ZIN Technologies

28th Annual Meeting of the American Society for Gravitational and Space Research

Twenty Years of Acceleration Measurements in Low-G Environments

Over a Decade of Support for the International Space Station

Kevin McPherson
Jennifer Keller
Eric Kelly
Ken Hrovat

ACRONYM	Definition
ARED	Advanced Resistive Exercise Device
ATV	Automated Transfer Vehicle
BASS	Burning And Suppression of Solids
CASIS	Center for the Advancement of Science in Space
CEVIS	Cycle Ergometer with Vibration Isolation System
CIR	Combustion Integrated Rack
FIR	Fluids Integrated Rack
GRC	Glenn Research Center
HiRAP	High Resolution Accelerometer Package
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
MAMS	Microgravity Acceleration Measurement System
MSG	Microgravity Science Glovebox
NASA	National Aeronautics and Space Administration
OARE	Orbital Acceleration Research Experiment
OSS	OARE Sensor Subsystem
PCSA	Principal Component Spectral Analysis
PIMS	Principal Investigator Microgravity Services
PSD	Power Spectral Density
RMS	Root Mean Square
RTS	Remote Triaxial Sensor
SAMS	Space Acceleration Measurement System
SE	Sensor Enclosure
T2	Treadmill 2
TB	Terabytes
TSH-ES	Triaxial Sensor Head Ethernet Standalone

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Outline

1. Capabilities and Services
2. Science Support and Customers

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3. Timeline of Acceleration System Deployment
4. Current Sensor Locations on the ISS

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if time allows, then some detail slides

8. Reboosts
9. Ku-Band Antenna
10. When Should I Run My Experiment?
11. ARIS Attenuation During FIR Ops
12. Structural “Mode One”

Capabilities and Services

- **NASA GRC** - continued goal of providing timely and readily accessible acceleration data, along with archival and analysis services for scientific payloads, structural dynamics monitoring, and technology developers.

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  - has ability to instrument and measure local vibratory regime in all 3 of the ISS labs, including throughout the USL ($0.01 \leq f \leq 300$ Hz).
  - given approval for upgrading the control unit, which provides a more robust, long-term solution for continued life-cycle support of the ISS.

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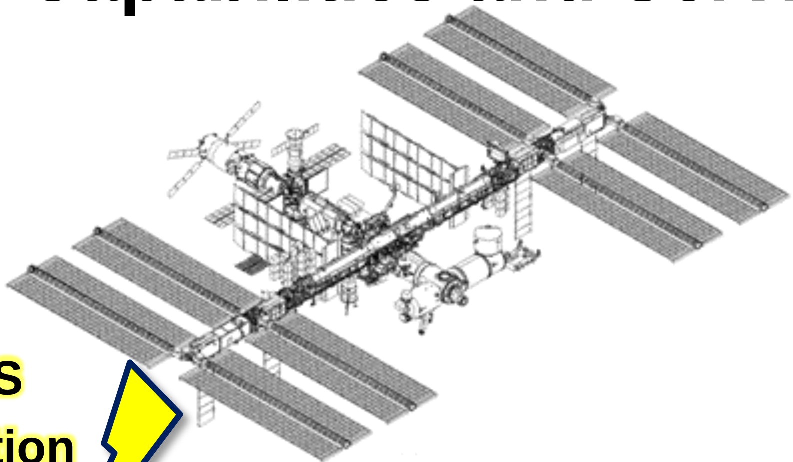
- **PIMS** - the Principal Investigator Microgravity Services team maintains the acceleration data from the ISS and provides analysis and related services for investigators, sustaining engineering, and the microgravity community at-large.

Capabilities and Services



24x7

SAMS & MAMS

stream acceleration data from the ISS to NASA GRC

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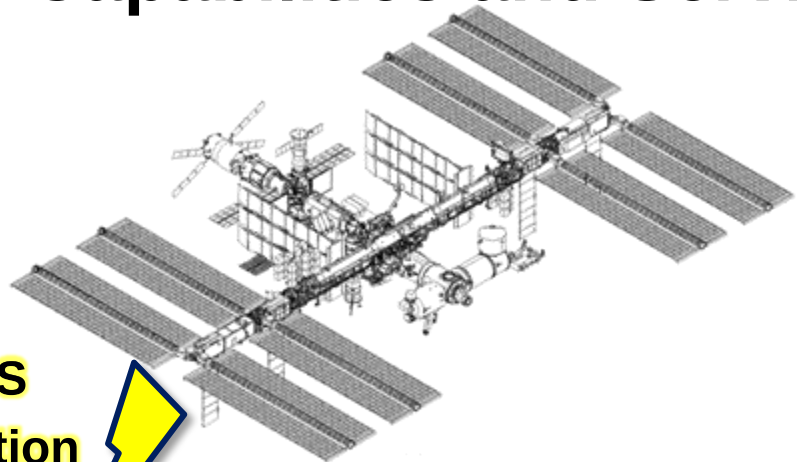
Capabilities and Services



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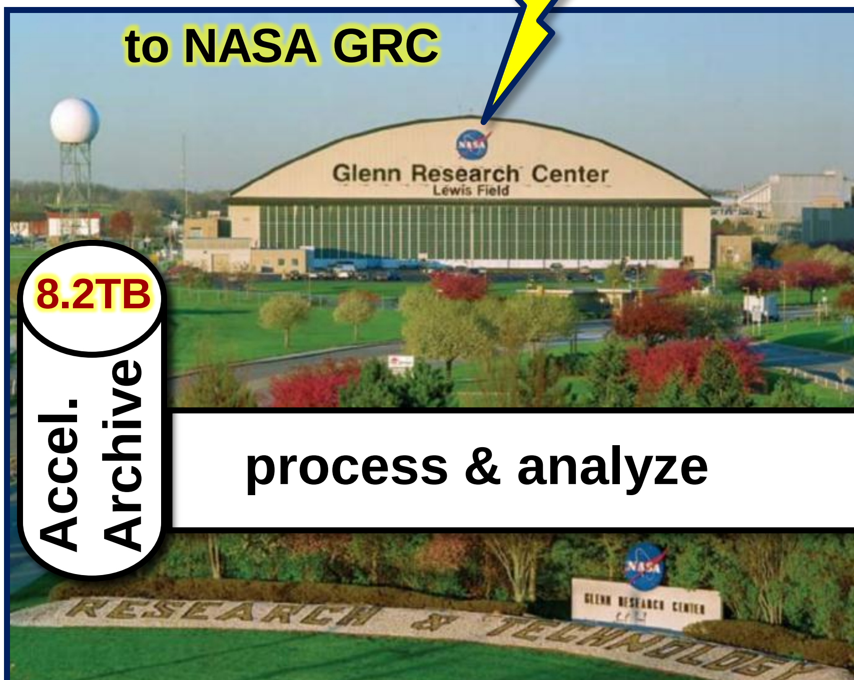

8.2TB

Accel. Archive

process & analyze

Web access to: near real-time displays, acceleration archives, and tailored off-line requests

http://pims.grc.nasa.gov

pimsops@grc.nasa.gov

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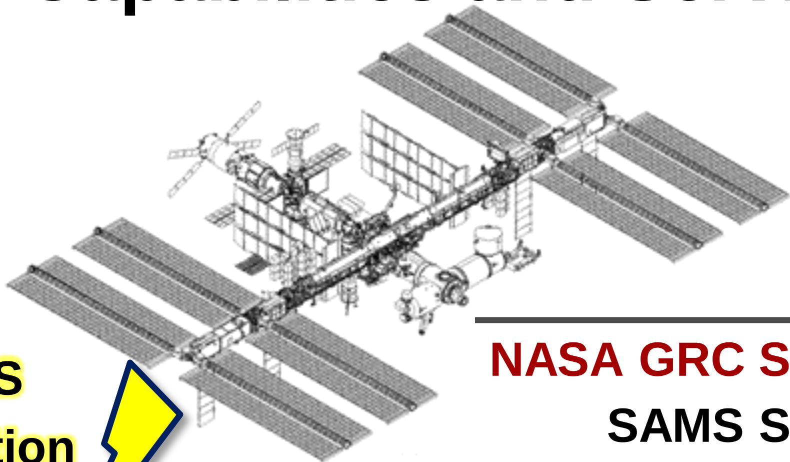
Capabilities and Services



Start Date =	5/3/2001
Stop Date =	11/23/2012
Hours ~	101,328
NASA GRC Sensor Hours >	354,451
SAMS Sensor Hours >	214,911
MAMS Sensor Hours >	139,540

24x7

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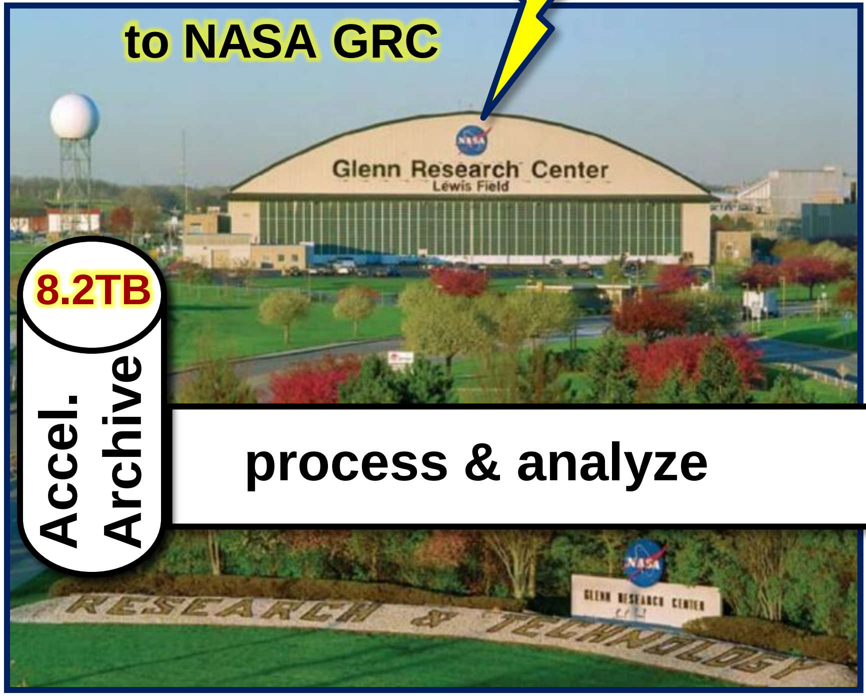

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Science Support and Customers

NASA's Physical Sciences Research Program conducts fundamental & applied research with experiments in:

Fluid Physics

Combustion Science

Materials Science

Fundamental Physics

Complex Fluids

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Complex Fluids

SAMS/MAMS were designed to support these disciplines, and along with **PIMS** for analysis, these **NASA GRC** projects also serve a role in ongoing support of:

Vehicle Loads and Dynamics Monitoring

Technology Developers

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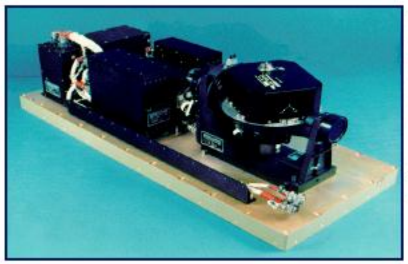
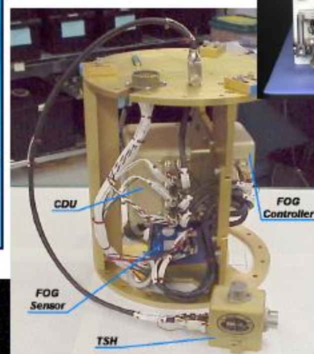
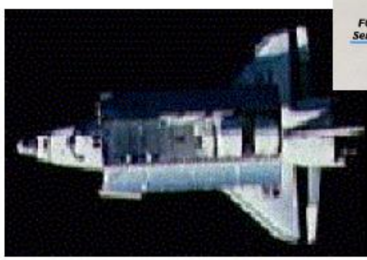
Outline

Timeline of Acceleration System Deployment





SAMS TSH-ES (Compact Ethernet Standalone)
(0.01 to 300 Hz) Station Vibratory

SAMS RTS (Ethernet Distributed)
(0.01 to 300 Hz) Station Vibratory

MAMS HiRAP
(0.01 to 100 Hz) Station Vibratory

MAMS OSS
(DC to 1 Hz) Station Quasi-Steady

RRS (0.1 arc/s)
1 sounding rocket, 1 shuttle

TSH-FF (0.01 to 200 Hz)
3 sounding rocket, 2 shuttle

OARE (DC to 1Hz) - 12 shuttle flights

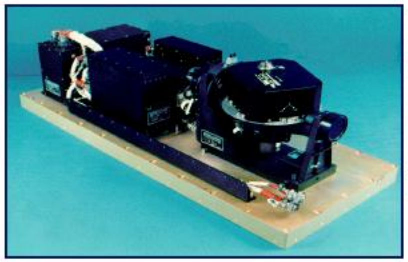
7 SAMS Units (0.01 to 100 Hz)
21 Shuttle/MIR Flights

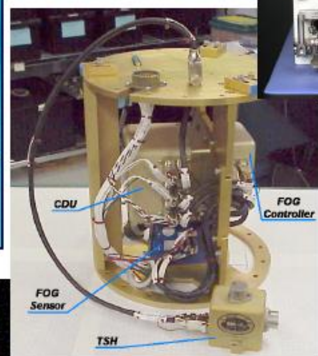
SAMS Project Initiated

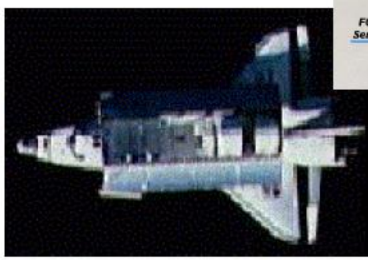
1986 1991 1994 1997 2000 2003 2006 2009 **2012** 2015 2018

YEAR

Timeline of Acceleration System Deployment







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on ISS from 2001 through 2028

SAMS Project Initiated

1986 1991 1994 1997 2000 2003 2006 2009 **2012** 2015 2018

YEAR

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Shuttle Missions with SAMS

STS-40 in 1991 → STS-107 in 2003

SORTED BY CARRIER

CARRIER		ACRONYM
Spacelab	Module	SLS-1
		IML-1
		USML-1
		SL-J
		IML-2
		USML-2
		LMS
		MSL-1
	MPESS	USMP-1
		USMP-2
		USMP-3
		USMP-4
SPACEHAB		SH-1
		SH-2
		SH-3
		SH-5
		SH-10
Middeck		STS-43
		ATLAS-3

SORTED BY DATE

DATE	FLIGHT	ACRONYM	PAYLOAD
June 5-14, 1991	STS-40	SLS-1	1st Spacelab for Life Sciences
August 2-11, 1991	STS-43		TDRS deployment
January 22-30, 1992	STS-42	IML-1	1st International Microgravity Laboratory
June 25 - July 9, 1992	STS-50	USML-1	1st US Microgravity Laboratory
September 12-20, 1992	STS-47	SL-J	Japanese Spacelab
October 22 - November 1, 1992	STS-52	USMP-1	1st US Microgravity Payload
June 21 - July 1, 1993	STS-57	SH-1	1st SPACEHAB
February 3-11, 1994	STS-60	SH-2	2nd SPACEHAB
March 4-18, 1994	STS-62	USMP-2	2nd US Microgravity Payload
July 8-23, 1994	STS-65	IML-2	2nd International Microgravity Laboratory
November 3-14, 1994	STS-66	ATLAS-3	3rd Atmospheric Laboratory for Applications and Sciences
February 3-11, 1995	STS-63	SH-3	3rd SPACEHAB
October 20 - November 5, 1995	STS-73	USML-2	2nd US Microgravity Laboratory
February 22 - March 9, 1996	STS-75	USMP-3	3rd US Microgravity Payload
June 20 - July 7, 1996	STS-78	LMS	Life and Microgravity Spacelab
September 16-26, 1996	STS-79	SH-5	5th SPACEHAB, 4th Mir docking
April 4-8, 1997	STS-83	MSL-1	Microgravity Sciences Laboratory
July 1-17, 1997	STS-94	MSL-1R	Microgravity Sciences Laboratory Reflight
November 19 - December 5, 1997	STS-87	USMP-4	4th US Microgravity Payload
January 22-31, 1998	STS-89	SH-10	10th SPACEHAB, 8th Mir docking
January, 2003	STS-107		Multi-disciplinary Microgravity & Earth Science Research

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Outline

Current Sensor Locations on the ISS

SAMS

SE F02, MSG upper left seat track

SE F03, ER2 lower Z panel

SE F04, ER1 lower Z panel

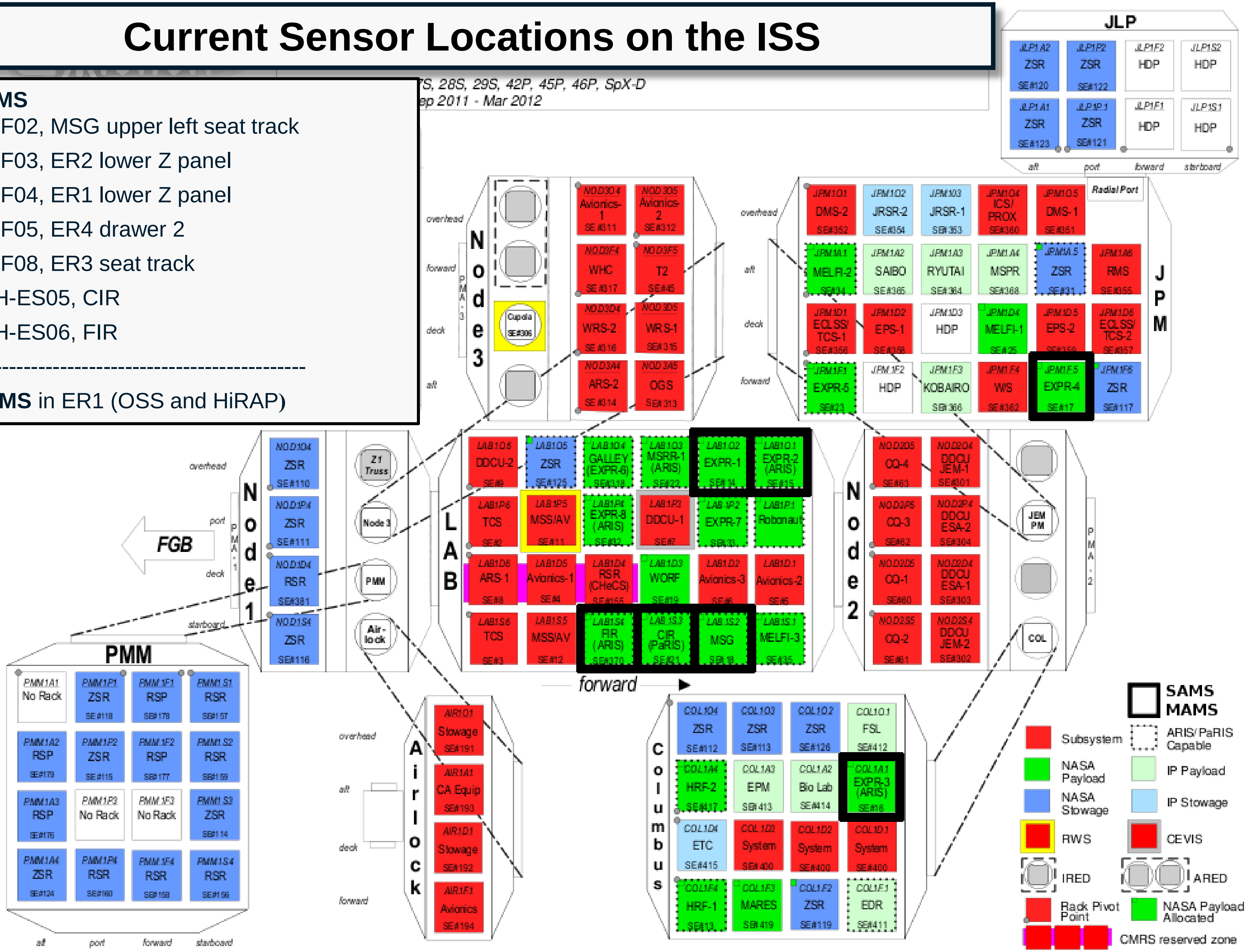
SE F05, ER4 drawer 2

SE F08, ER3 seat track

TSH-ES05, CIR

TSH-ES06, FIR

MAMS in ER1 (OSS and HiRAP)



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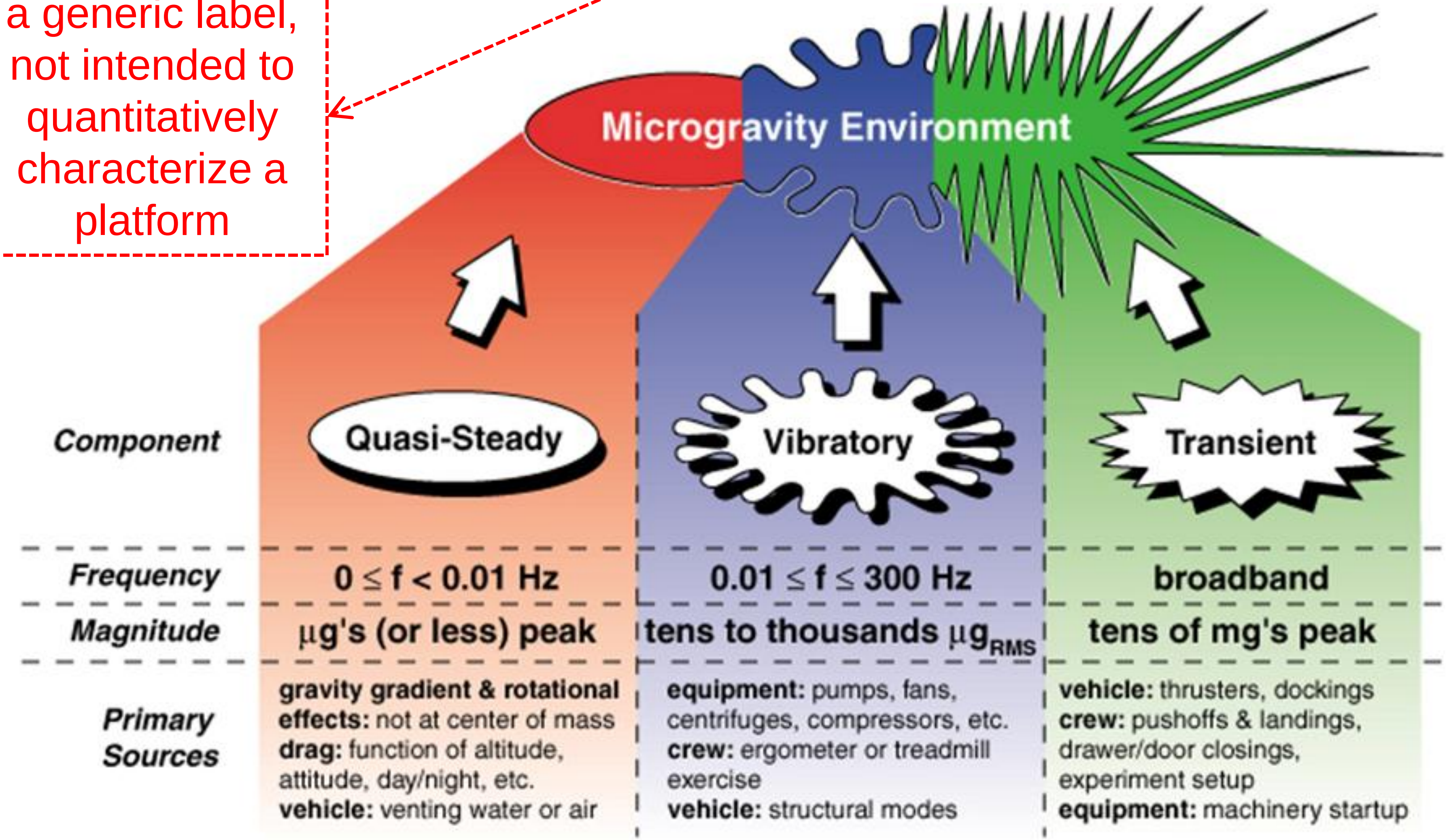
Basics of the Microgravity Environment

a generic label, not intended to quantitatively characterize a platform



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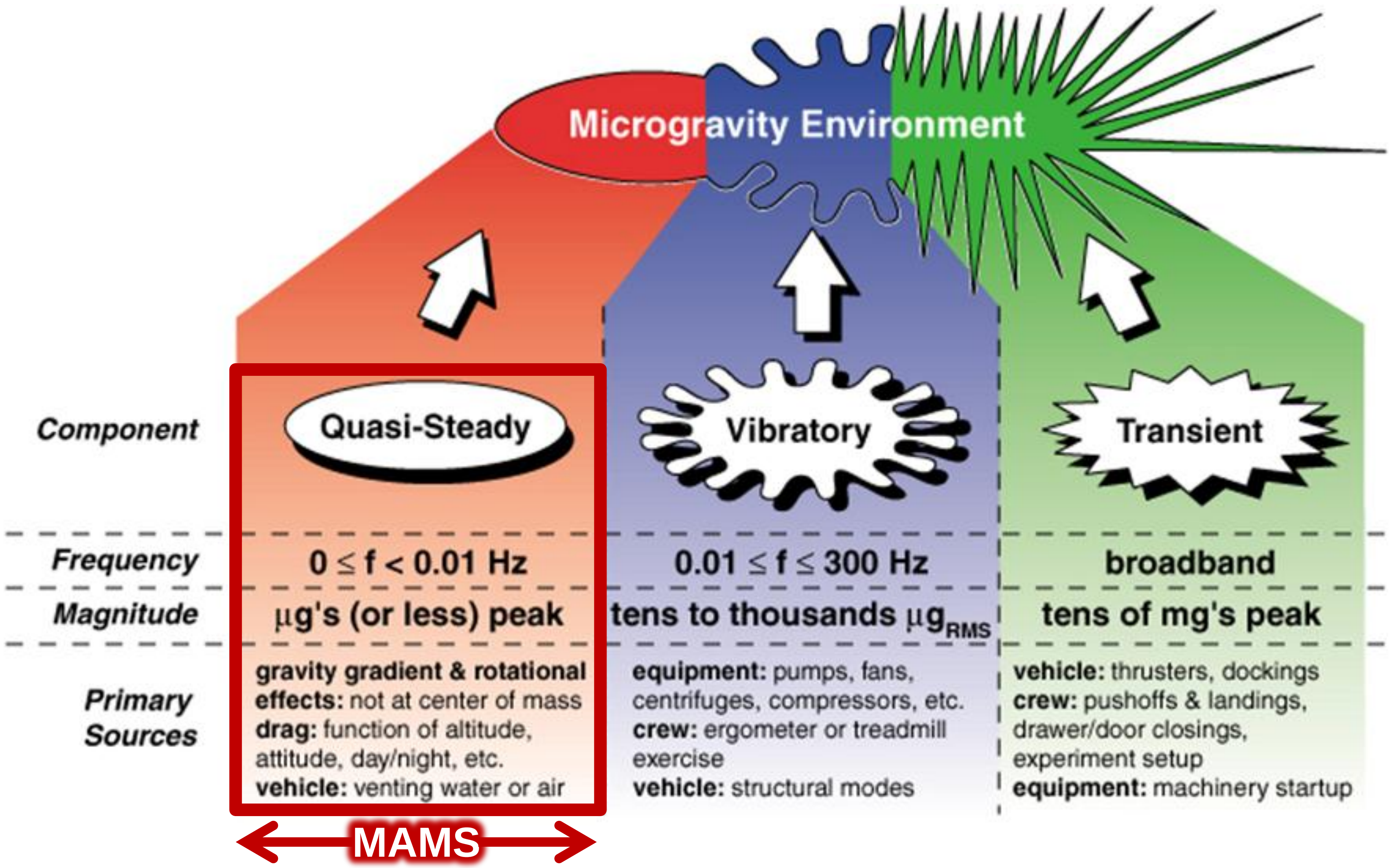

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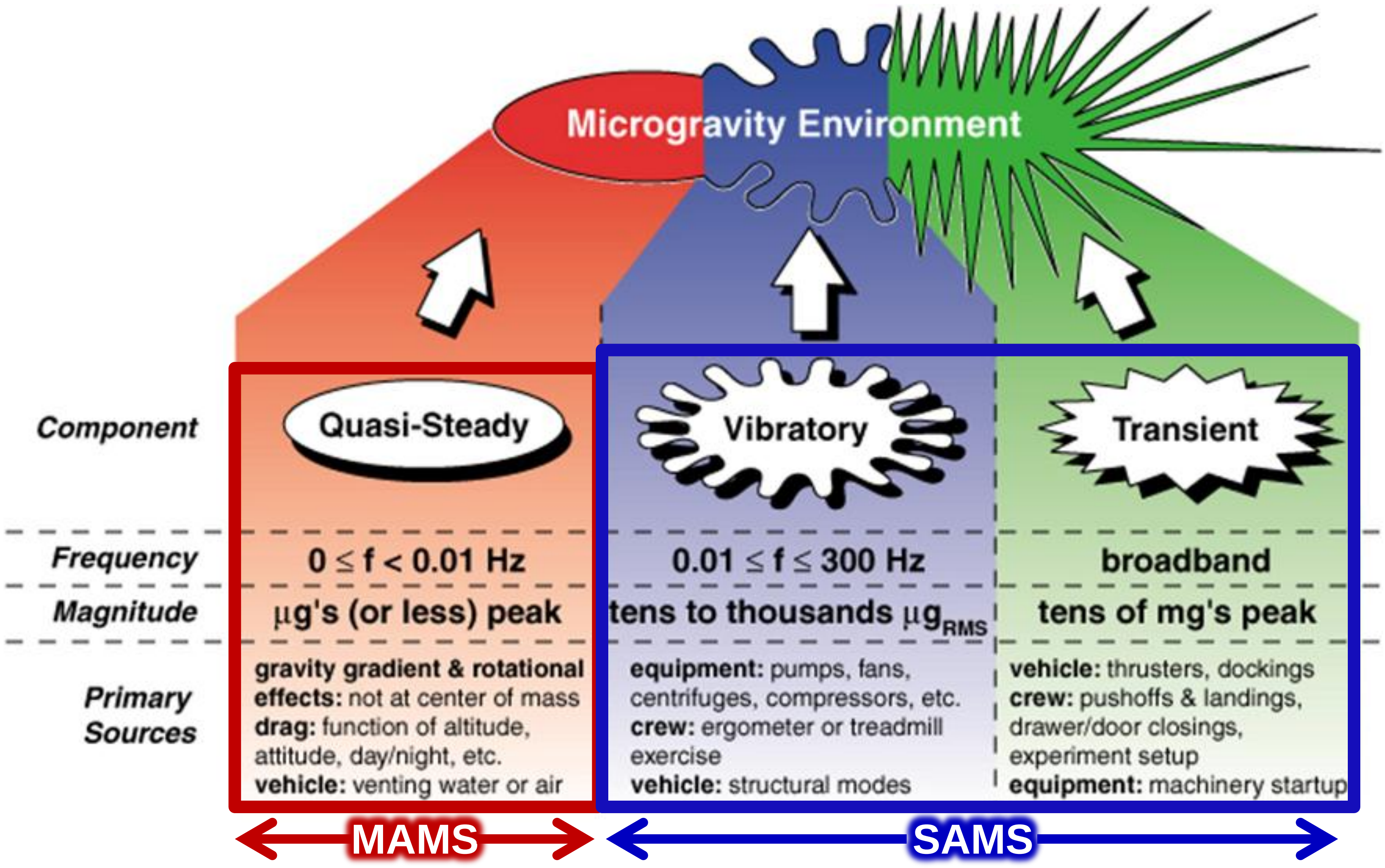
Basics of the Microgravity Environment



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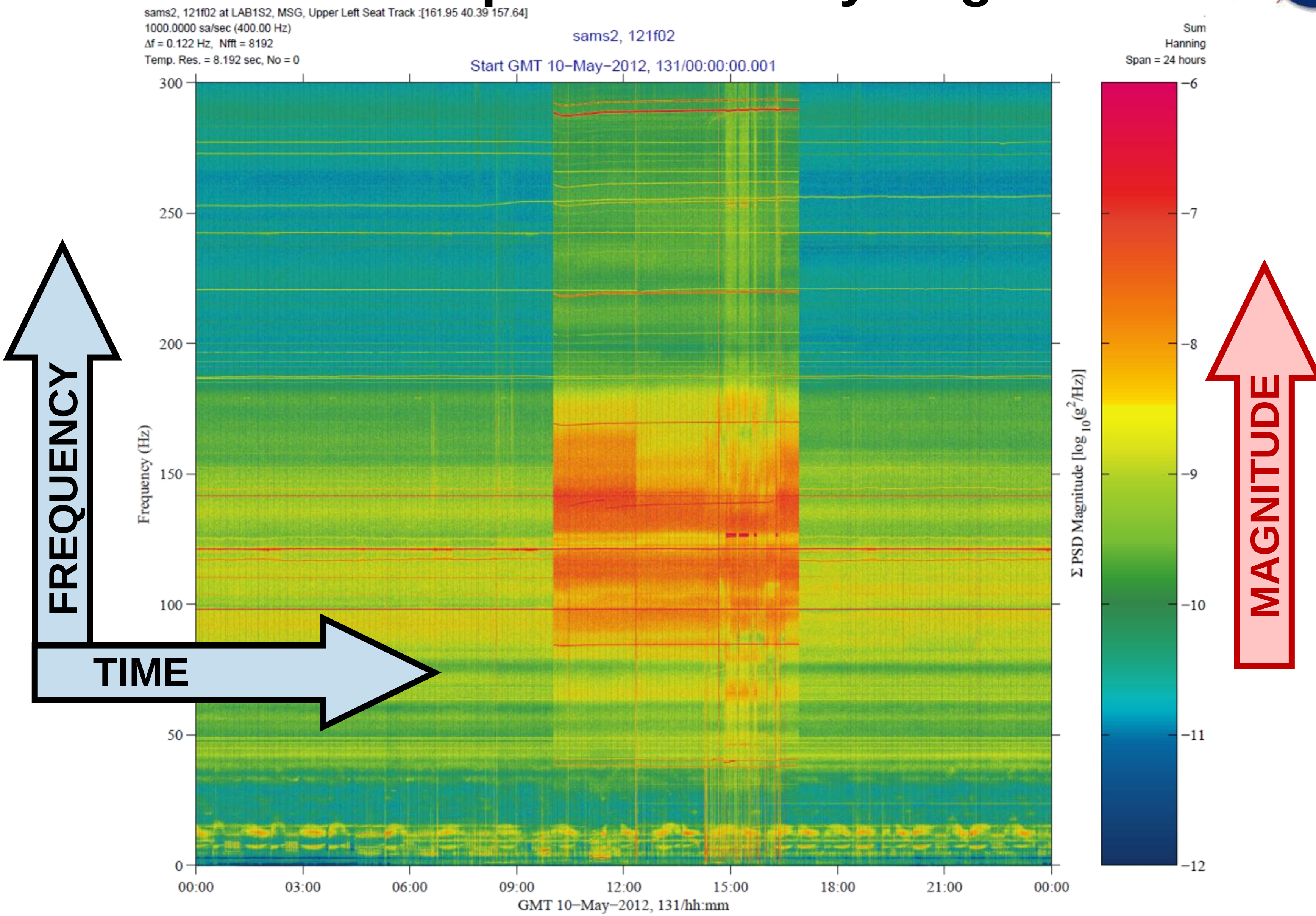
Roadmap for Vibratory Regime

spectrogram is a “roadmap” that shows boundaries and structure in time and frequency

1. **Qualify**
2. **Quantify**

Roadmap for Vibratory Regime



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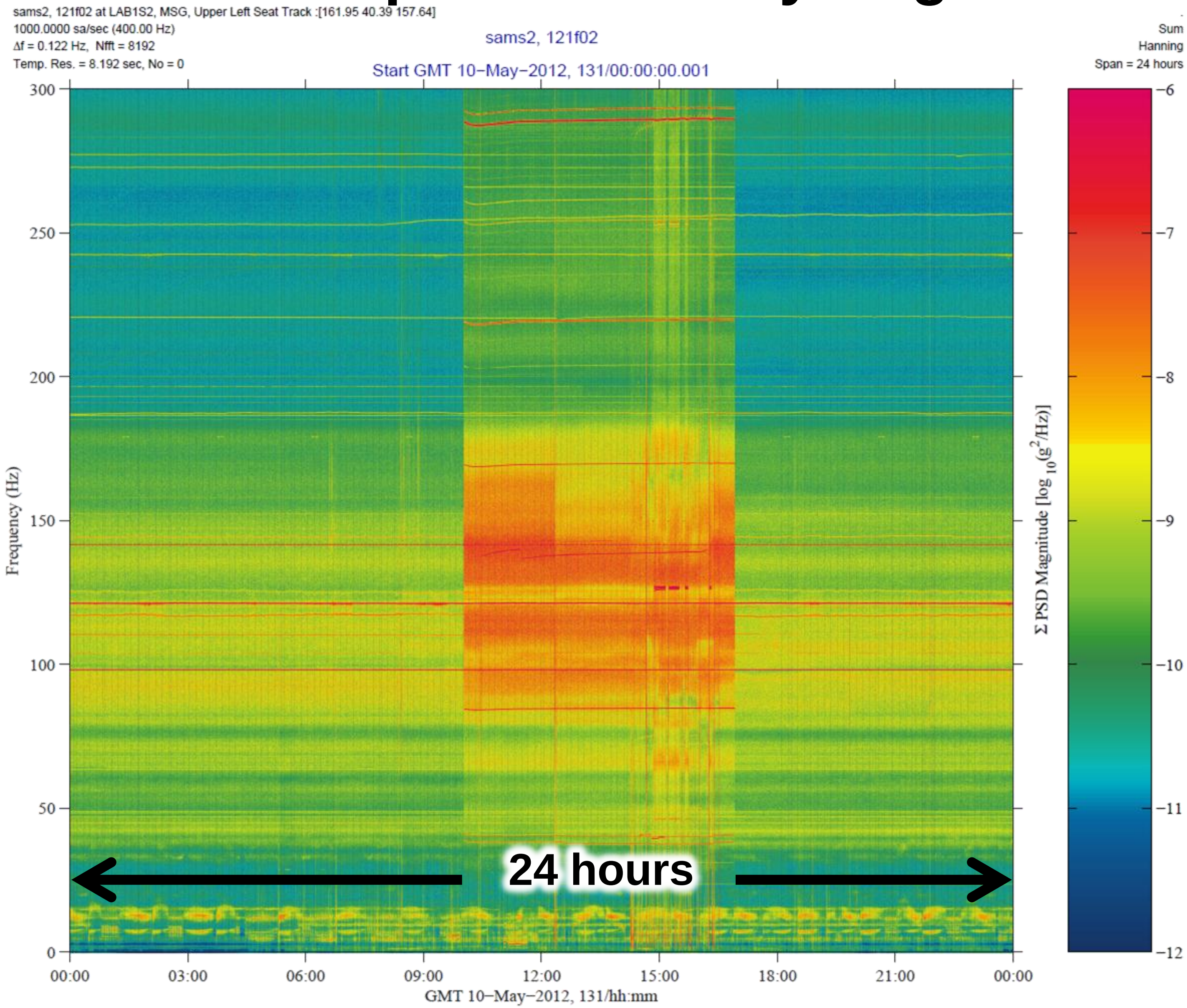
Roadmap for Vibratory Regime



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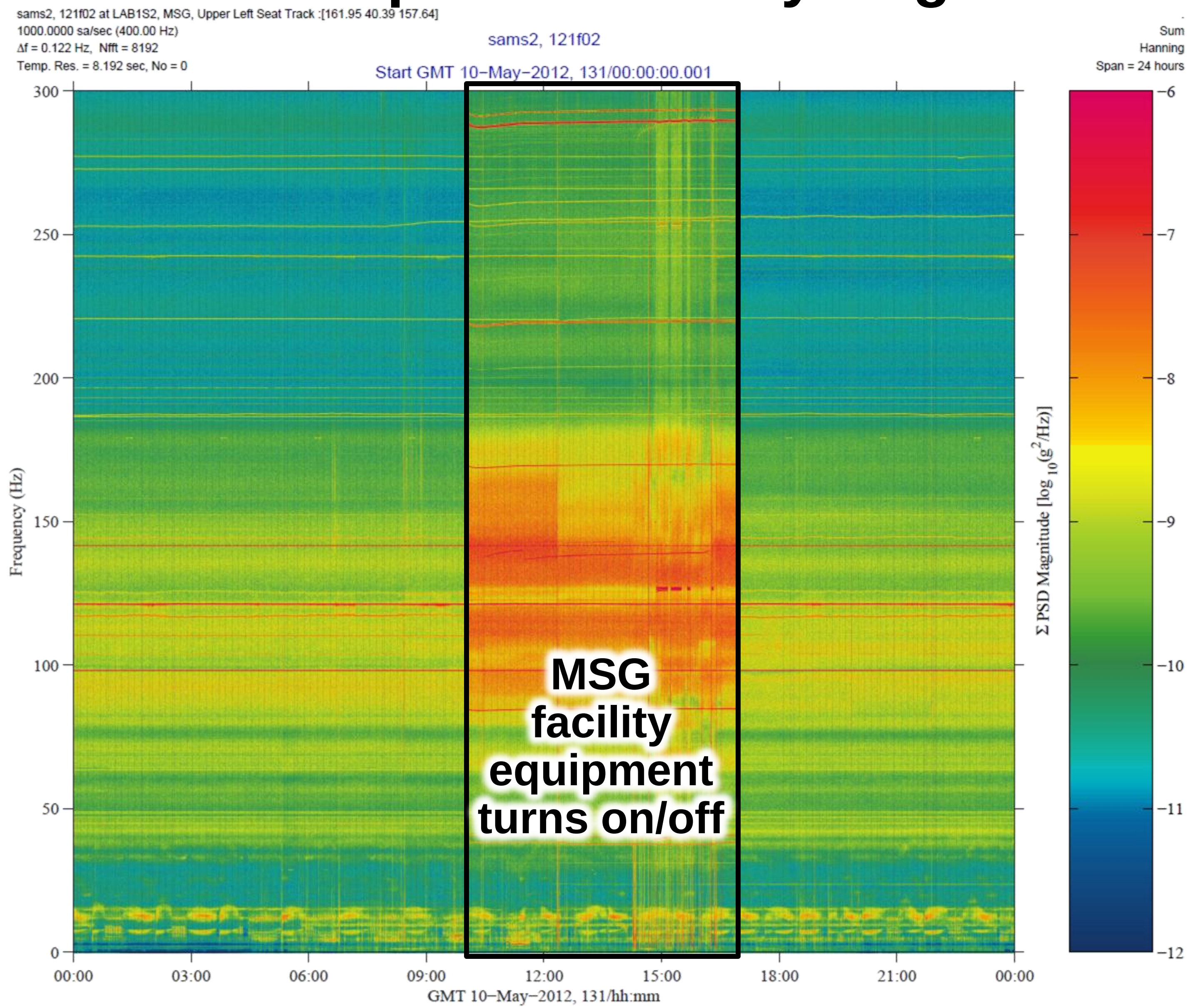

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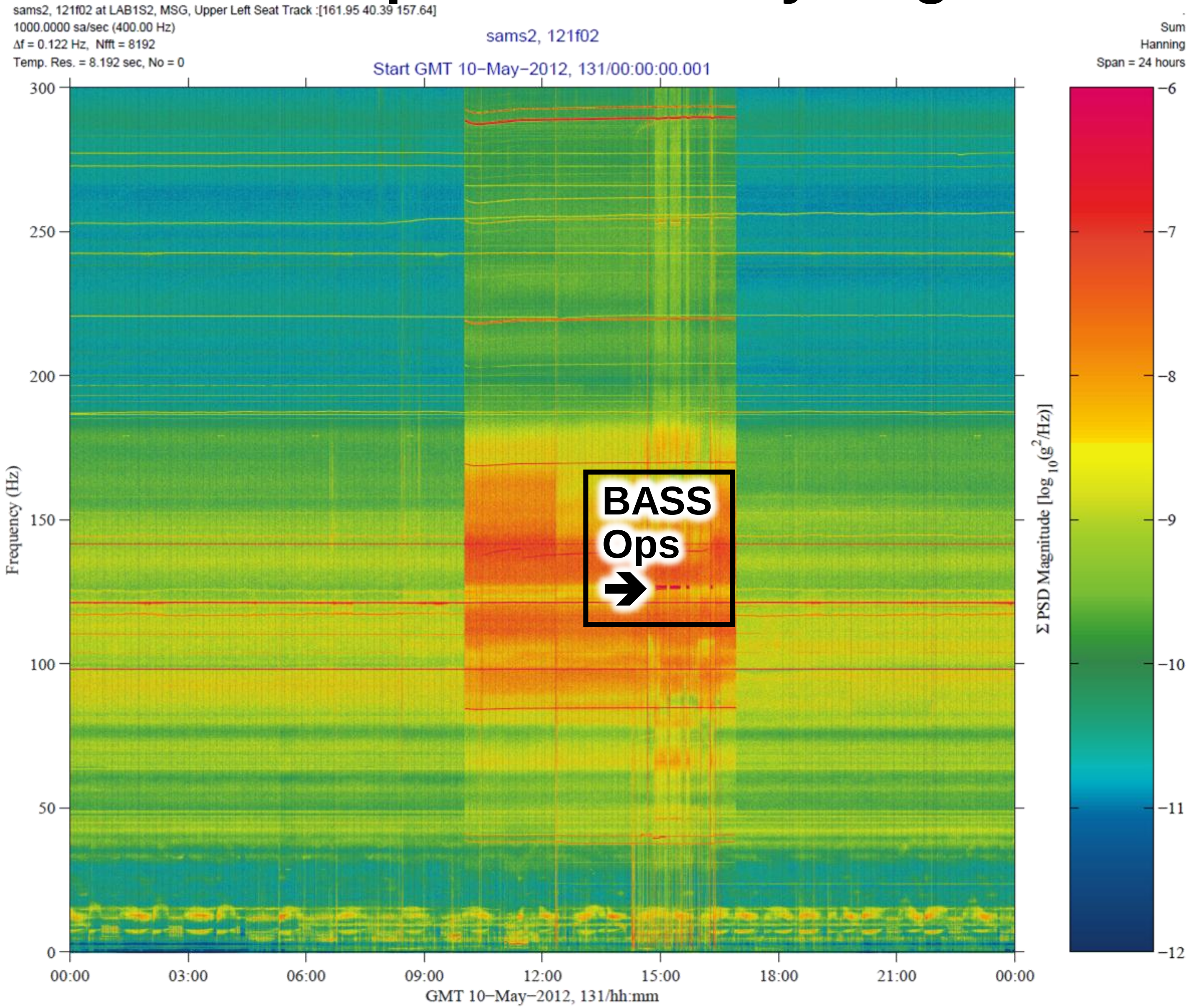

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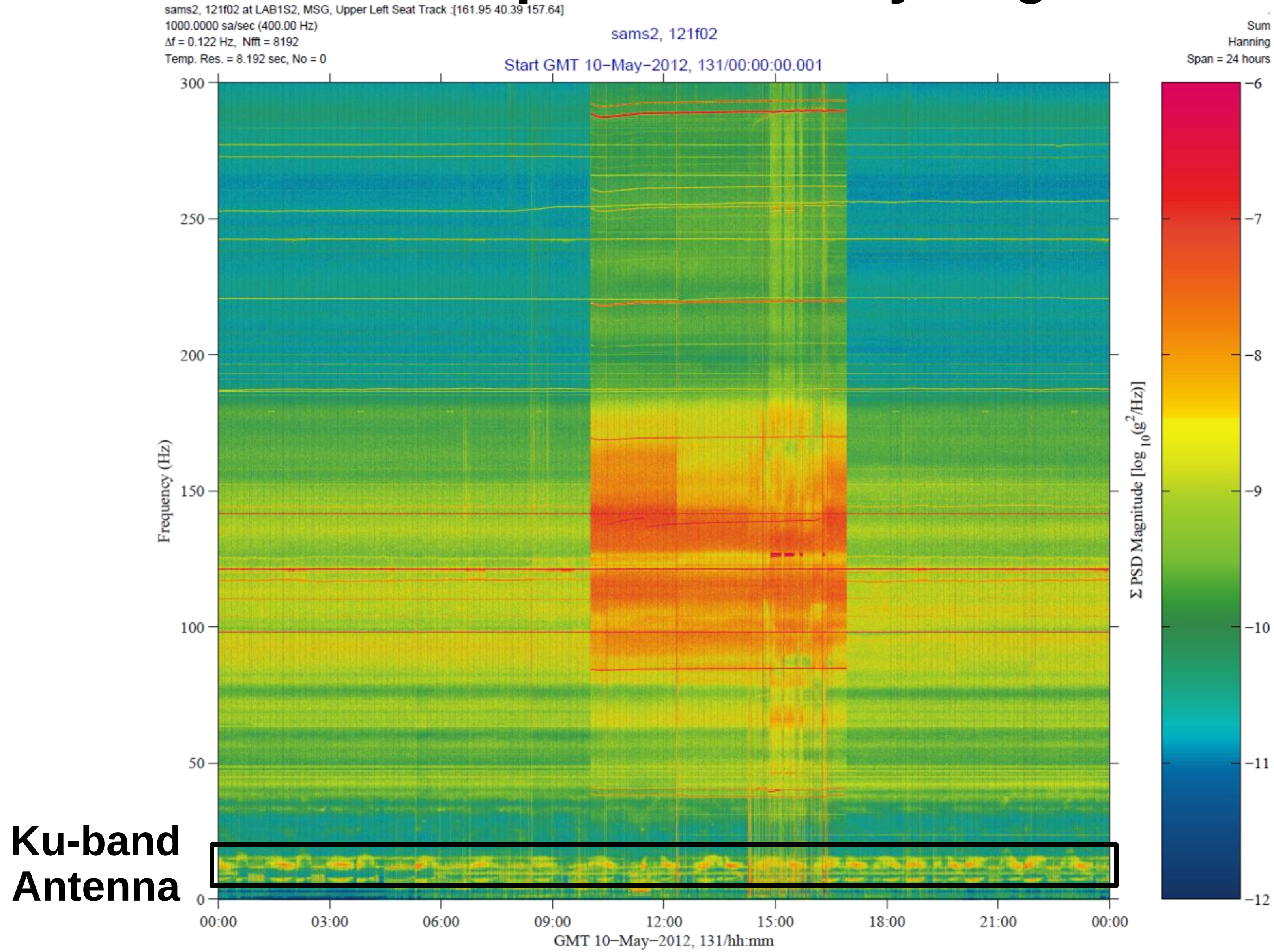

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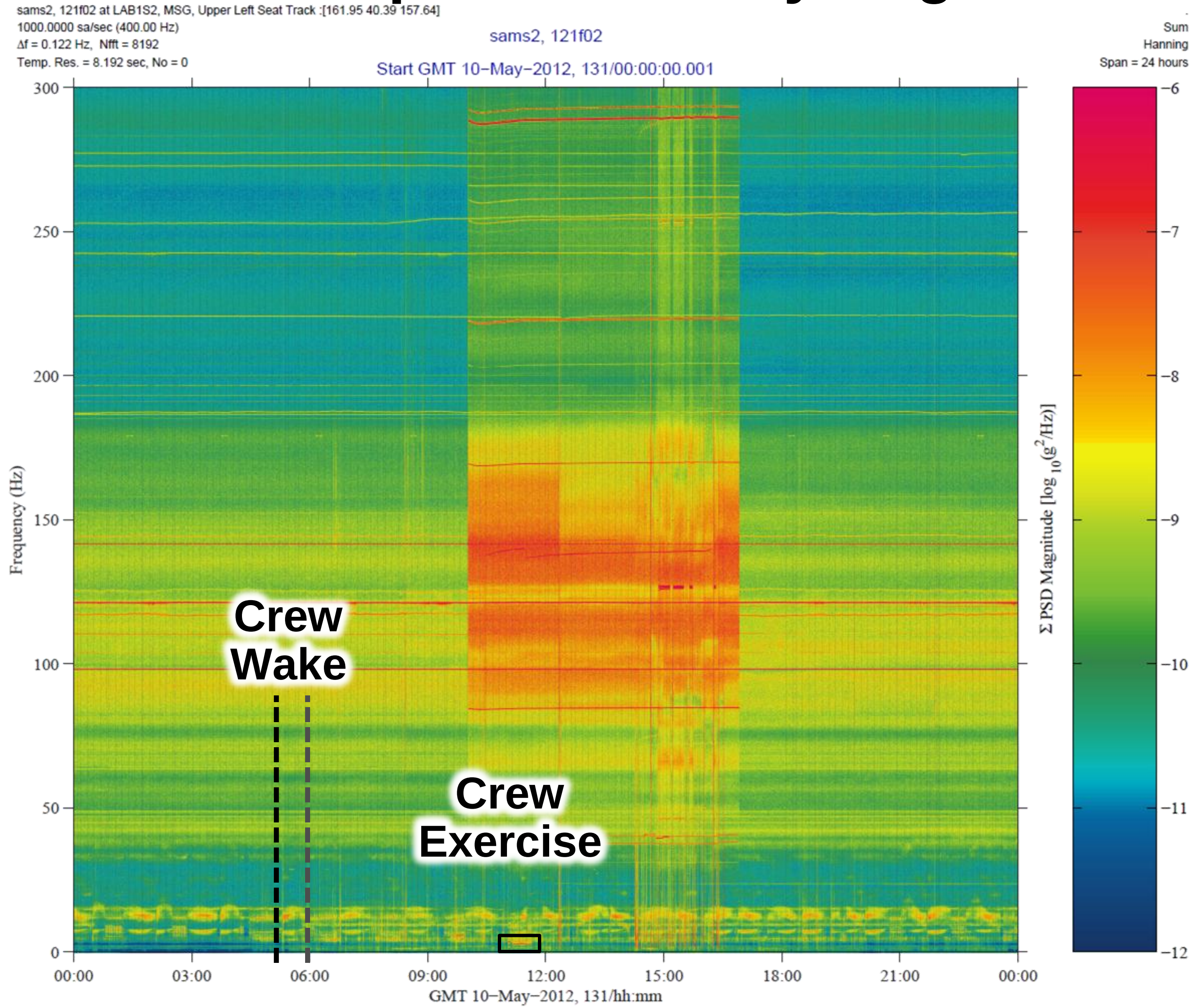

Roadmap for Quasi-Steady Regime

time series with primary focus on mean value and low-frequency components

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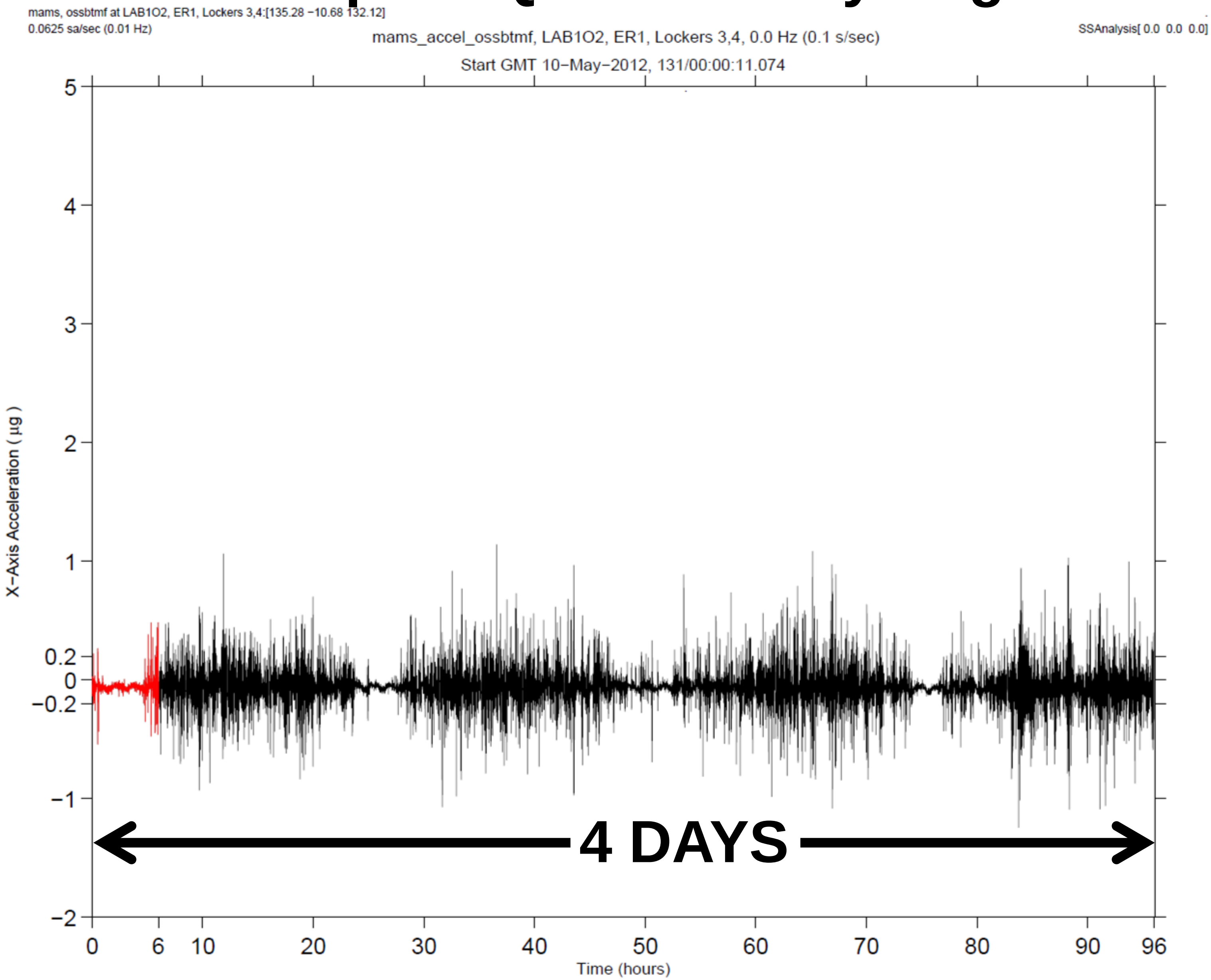
Roadmap for Quasi-Steady Regime



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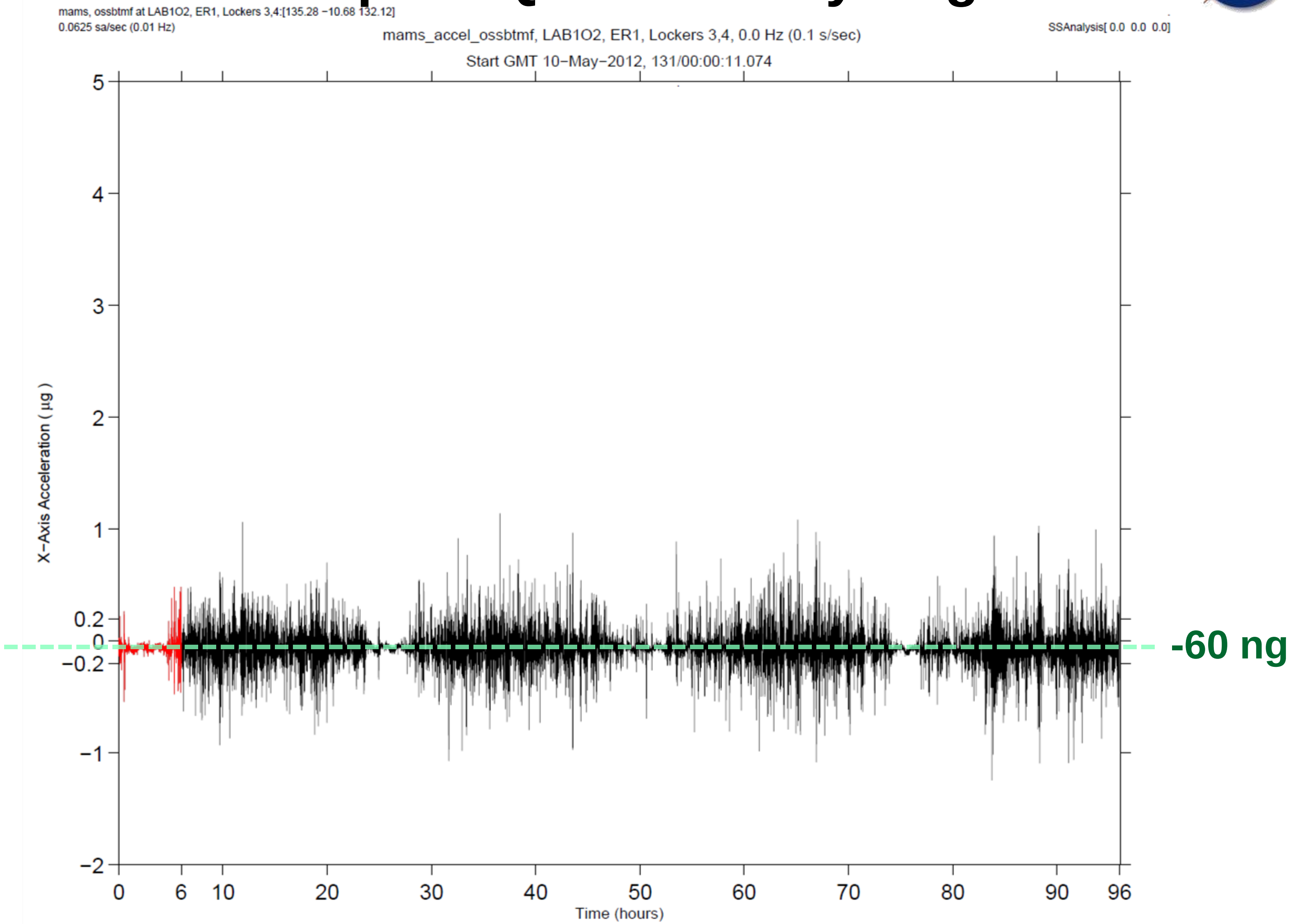

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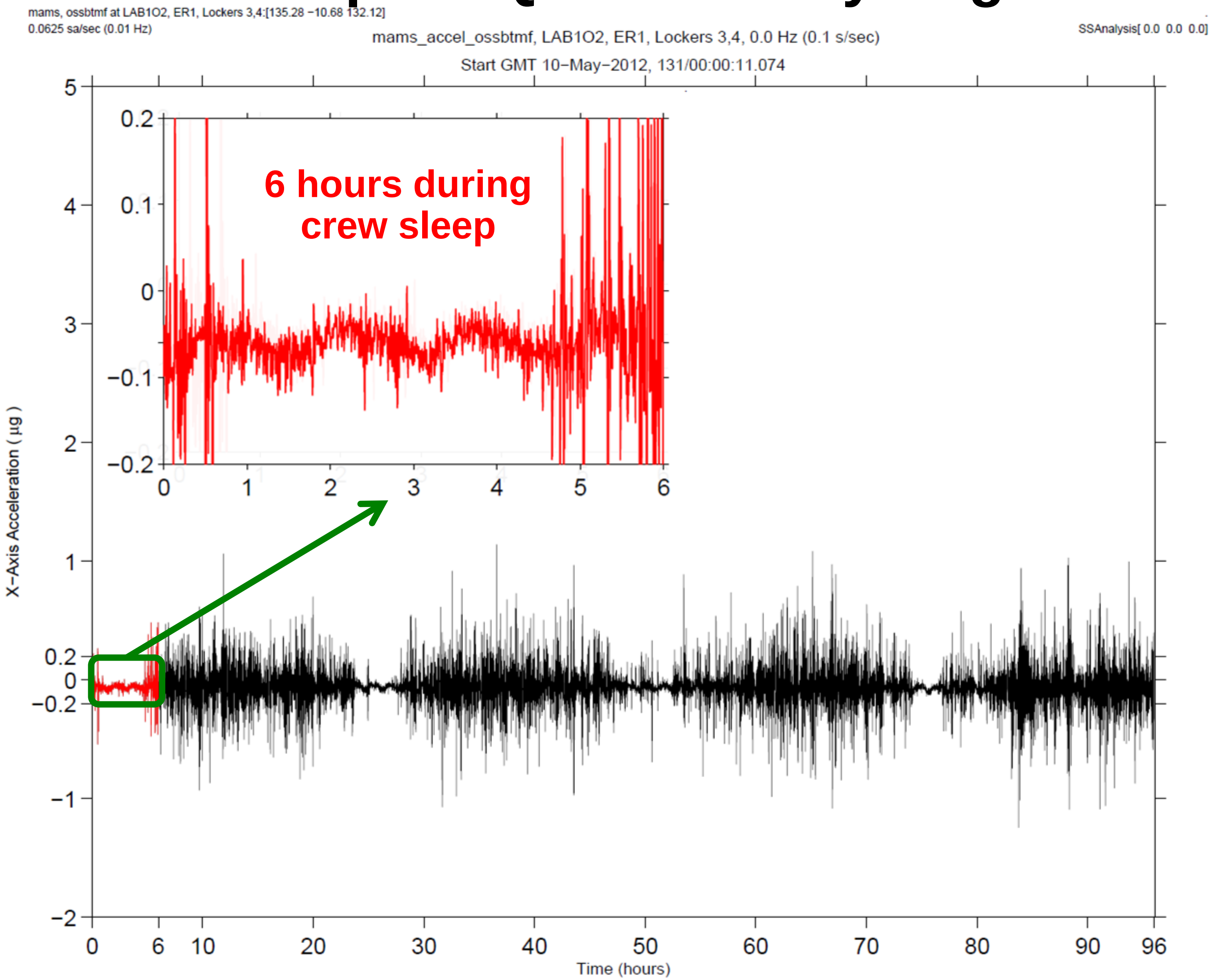

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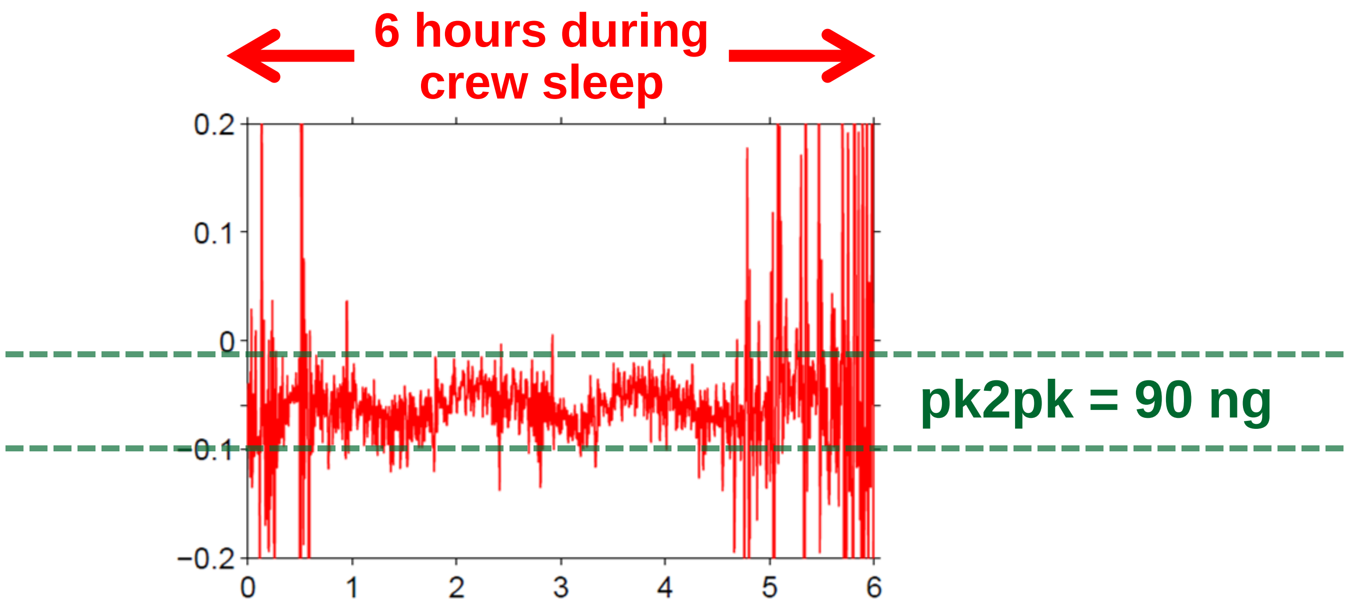

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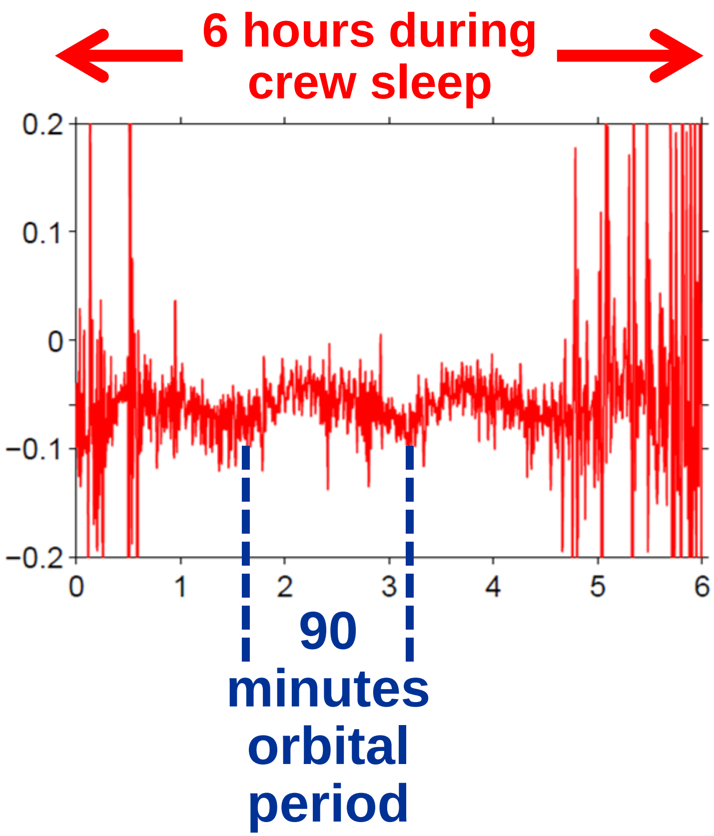

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Brief Characterization of Some Disturbances

Source	Brief Characterization Notes
Progress Reboost*	duration = 11.4 minutes, x-axis step = 0.4 mg ** mean values based on 24 reboosts*
ATV3 Reboost	duration = 7.0 minutes, x-axis step = 0.3 mg
Mode One	~0.1 Hz, fund. mode of main truss monitored daily by loads and dynamics team USL < 2 ugRMS, COL & JEM < 3 ugRMS (Sept. 2012)
GLACIER Ops	two narrowband spectral peaks: (1) 162 ugRMS @ 60 Hz, (2) 112 ugRMS @ 120 Hz
Ku-Band Antenna	5 to 17 Hz, nom. < 500 ugRMS with orbital period variations
MSG Ops	broadband, step up 536 ugRMS for f < 200 Hz
Robonaut Ops	narrowband peak: 50 ugRMS @ ~47 Hz
ARIS Attenuation	0.01 to 20 Hz, step down from ~100 to ~10 ugRMS (FIR ops)
CCAA	fan: ~57 Hz or ~95 Hz, ~510 ugRMS water separator: ~98 Hz, ~234 ugRMS
Crew Sleep/Wake	difference primarily below about 6 Hz: **USL during sleep ~11.8 ugRMS, during wake ~23.9 ugRMS** **JEM during sleep ~15.2 ugRMS, during wake ~34.6 ugRMS** **COL during sleep ~17.3 ugRMS, during wake ~37.7 ugRMS**

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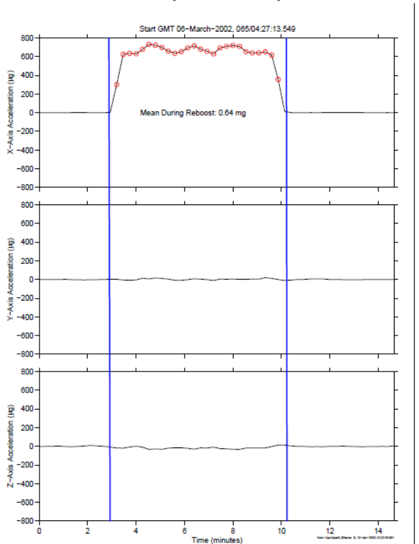
Progress Reboosts

Progress Reboost



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)

Microgravity Science Division

Glenn Research Center

PIMS ISS Acceleration Handbook
Date last modified 10/20/04

Progress Reboost

The table below compares average acceleration from vehicle data to the average acceleration calculated from MAMS

Reboost Information					Calculations from MAMS OSS data		
Ignition (GMT)	Comments	Δ V (m/sec)	Duration (sec)	ΔV/T (mg)	Duration (sec)	ΔV (m/sec)	X-Axis Mean (mg)
11-Oct-2001, 284/10:31	4 Progress +X Thrusters	4.7	1560	0.31	1,629.30	4.63	0.29
11-Oct-2001, 284/15:54	4 Progress +X Thrusters	4.5	1560	0.29	1,623.78	4.46	0.28
10-Jan-2002, 010/01:35:15	4 Progress +X Thrusters	5.4	1877	0.29	1,863.90	5.3	0.29
10-Jan-2002, 010/03:43:26	4 Progress +X Thrusters	4.8	1654	0.30	1,643.00	4.67	0.29
21-Feb-2002, 052/08:27	8 Progress +X Thrusters, Off-Pulsing	1.35	239	0.58	237.40	1.21	0.52
21-Feb-2002, 052/09:59	8 Progress +X Thrusters, Off-Pulsing	1.35	243	0.57	238.50	1.24	0.53
06-Mar-2002, 065/03:37:12	8 Progress +X Thrusters, Off-Pulsing	1.0	158.2	0.65	157.70	0.93	0.60*
06-Mar-2002, 065/04:29:07	8 Progress +X Thrusters, Off-Pulsing	2.5	395.1	0.65	398.80	2.5	0.64*
13-Mar-2002, 072/00:04:10	8 Progress +X Thrusters, Off-Pulsing	2.2	319	0.70	300.30	1.8	0.61*
13-Mar-2002, 072/00:52:49	8 Progress +X Thrusters, Off-Pulsing	4.0	636.1	0.64	609.70	3.94	0.66*
19-Apr-2002, 109/07:59	8 Progress +X Thrusters, Off-Pulsing	0.73	118	0.63	142.70	0.6	0.43
01-Aug-2002, 213/17:24:23	8 Progress +X Thrusters, Off-Pulsing	4.3	760	0.58	761.10	4.18	0.56
11-February-2003 042/11:34:30	8 Progress +X Thrusters, Off-Pulsing	5.1	~1200	0.43	1168	4.01	0.35
12-March-2003 071/22:58	Progress Manifold 1 4 Progress +X Thrusters	1.38	597	0.24	634	1.3	0.21
12-March-2003 072/23:37	Progress Manifold 2 4 Progress +X Thrusters	0.37	198	0.19	219	0.3	0.14
04-April-2003 094/12:59:18	8 Progress +X Thrusters Off-Pulsing	1.8	N/A	N/A	835	1.83	0.23
10-Apr-2003, 100/10:55	8 Progress +X Thrusters Off-Pulsing	1.48	661	0.23	672	1.43	0.22

Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (1 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increments: 3-9 Flights: Various
Plot Type	Time Series

NOTES:

- Reboost Information column contains estimates. This information was obtained from Rex Delventhal, GNC Daily Reports and/or On-Orbit Summaries.
- Values marked with an asterisk may be off by as much as 14 ug due to lack of bias compensation for OSS A-range data.

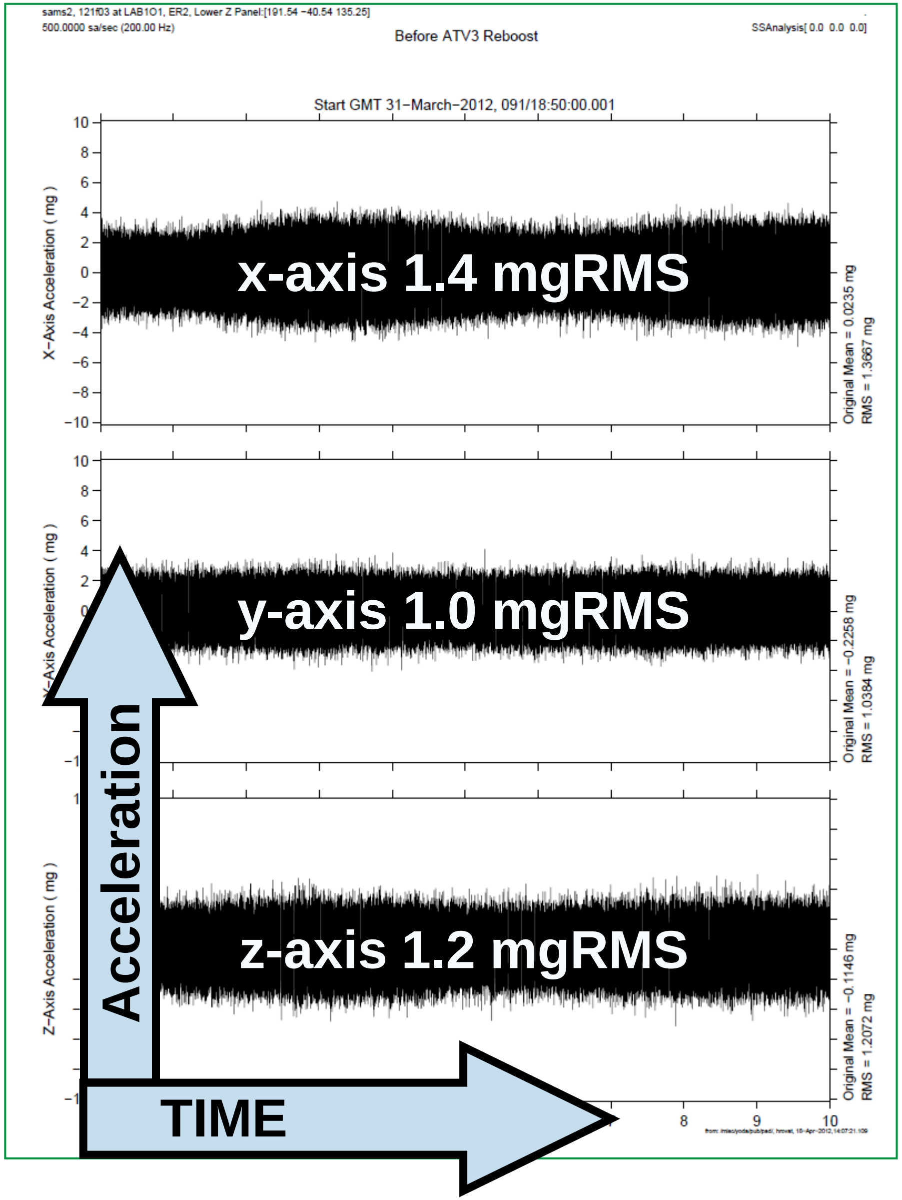
Regime:	Quasi-steady
Category:	Vehicle
Source:	Progress Thrusters

	duration(sec)	deltaV(m/s)	xMean(mg)
MEAN	686	2.36	0.39
STD	517	1.49	0.15

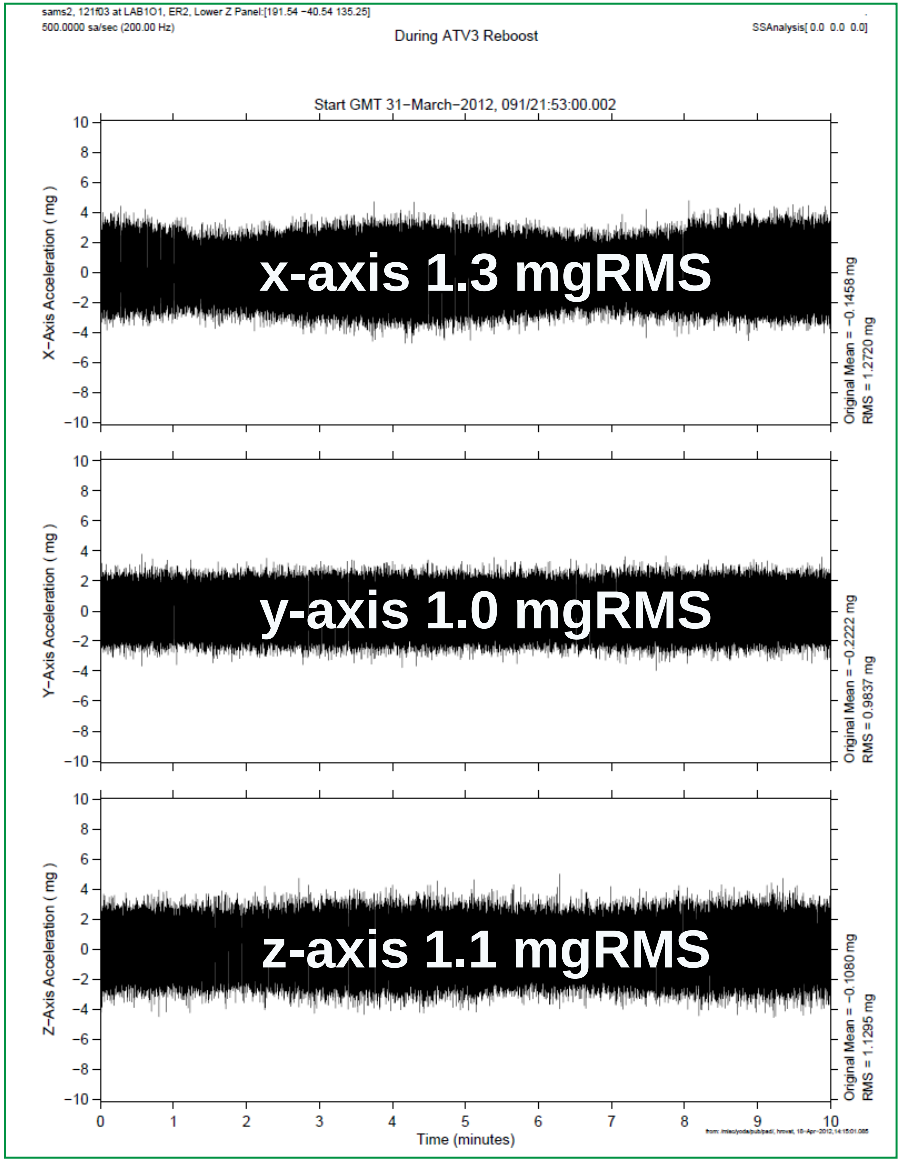
statistics for 24 reboost events

ATV3 Reboost GMT 31-Mar-2012

BEFORE

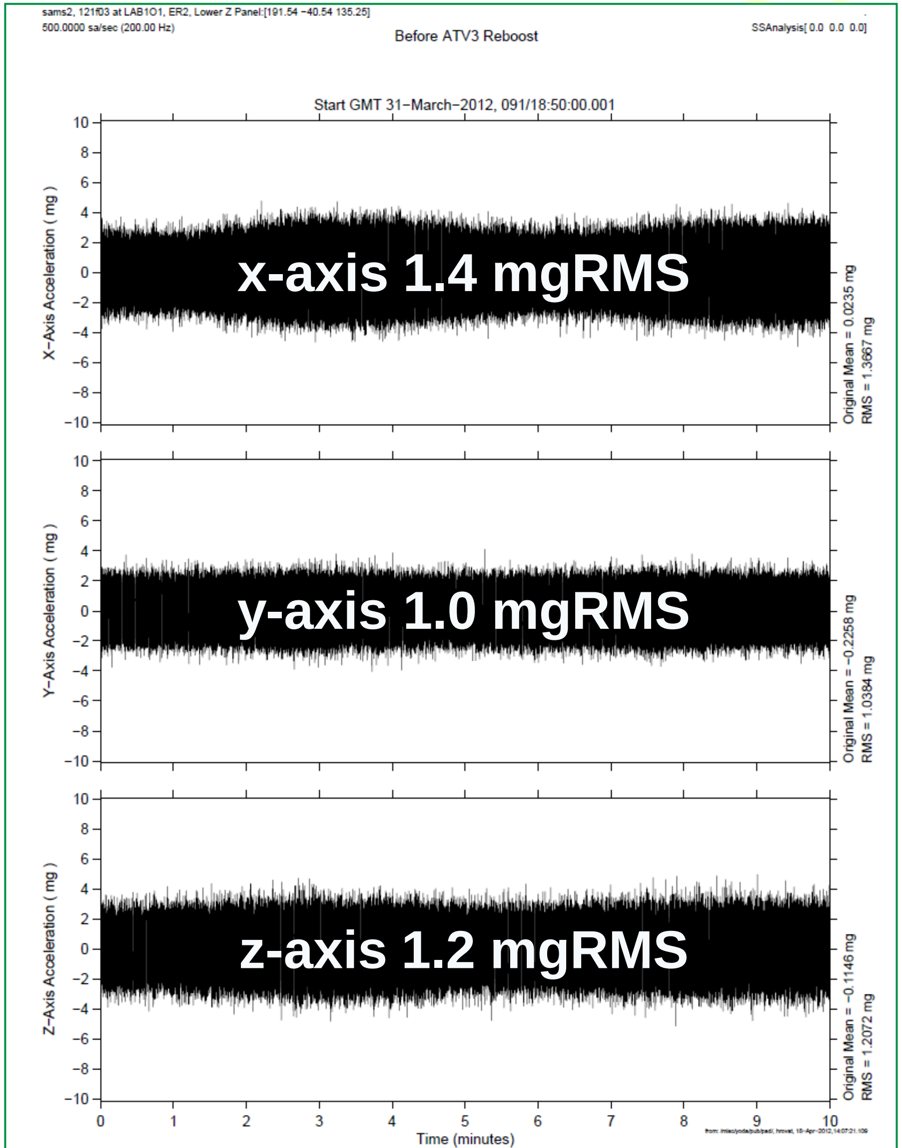


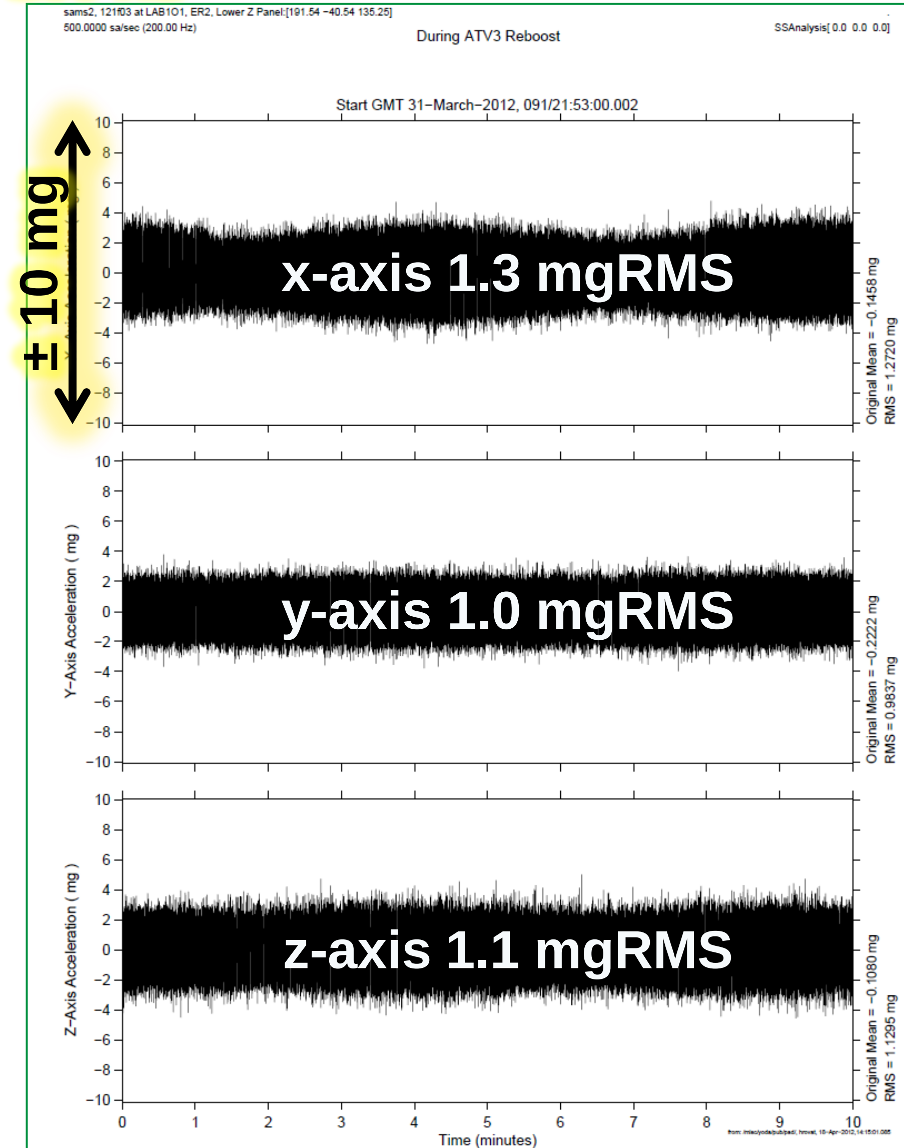
DURING



ATV3 Reboost GMT 31-Mar-2012

BEFORE **0 < f < 200 Hz** **DURING**





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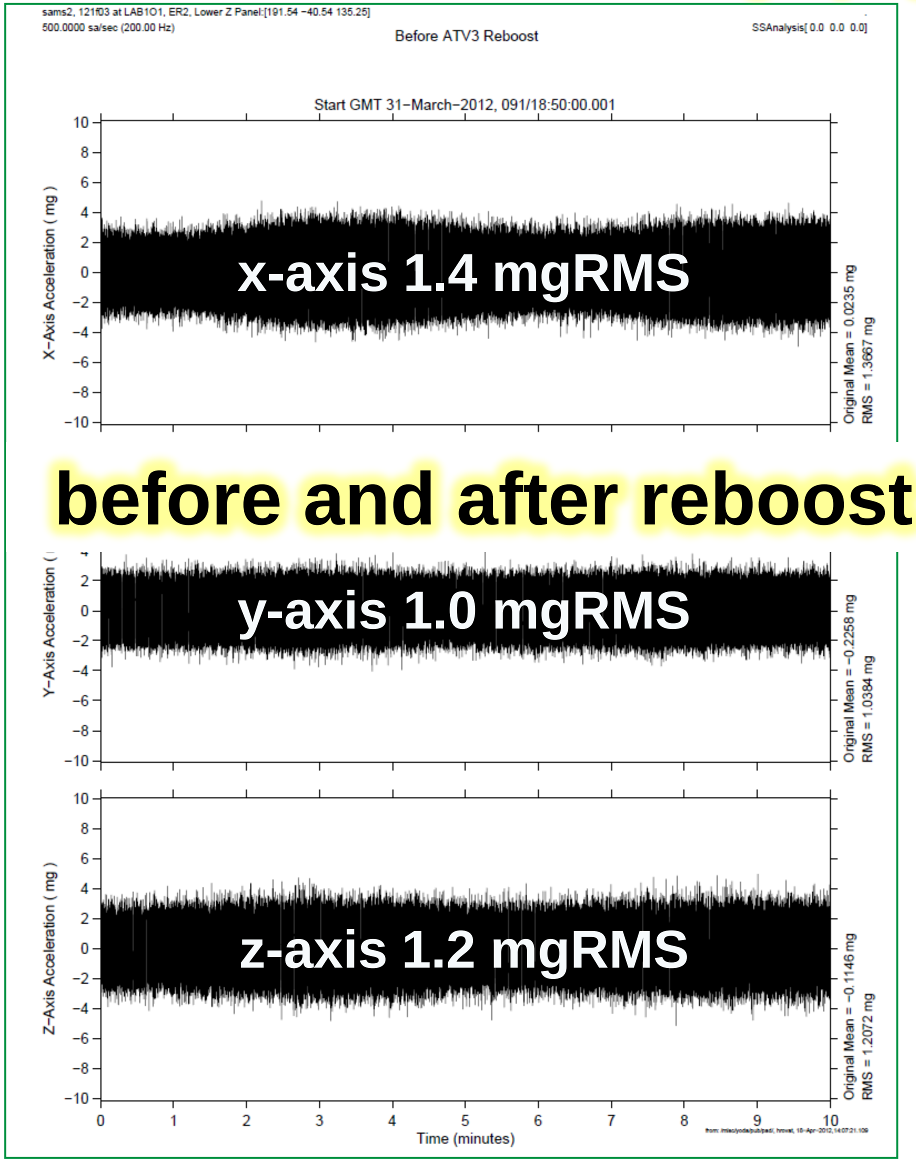
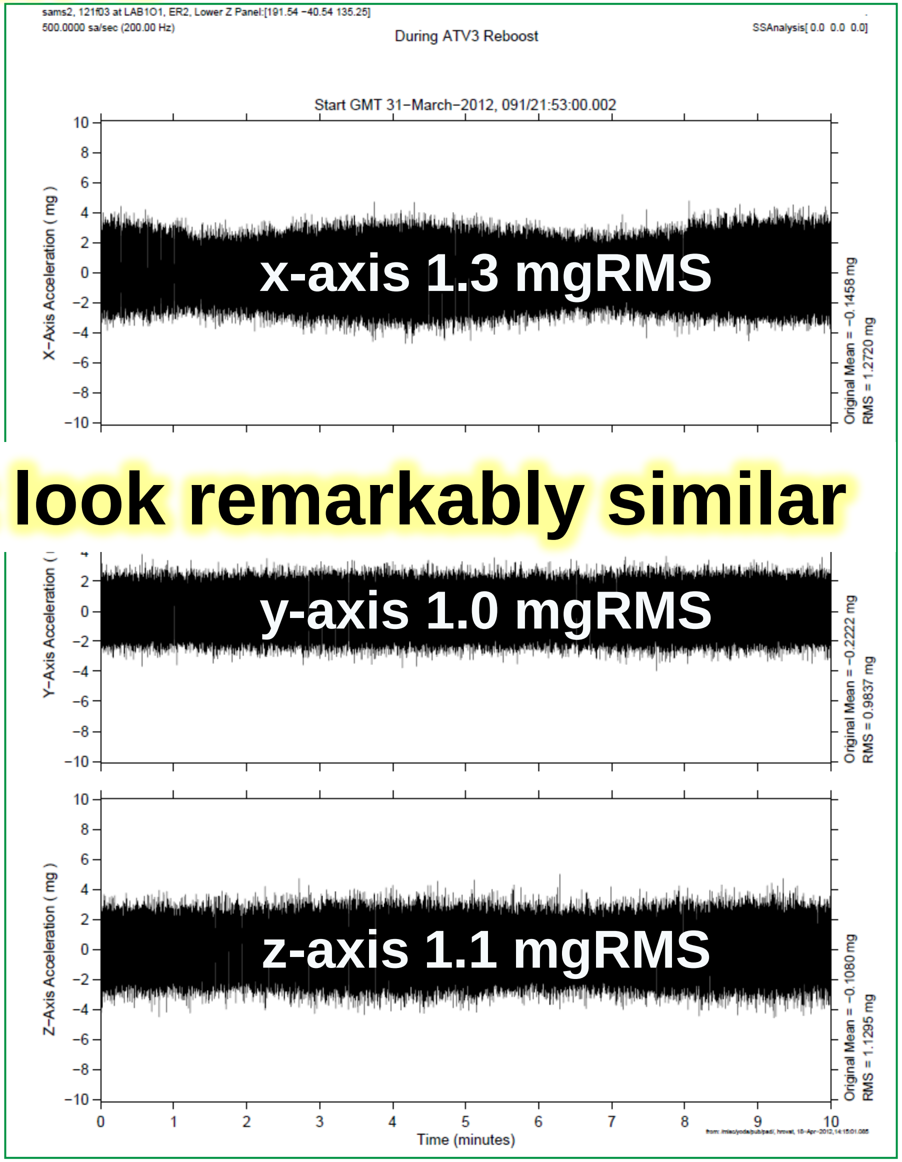
ATV3 Reboost GMT 31-Mar-2012

BEFORE **0 < f < 200 Hz** **DURING**



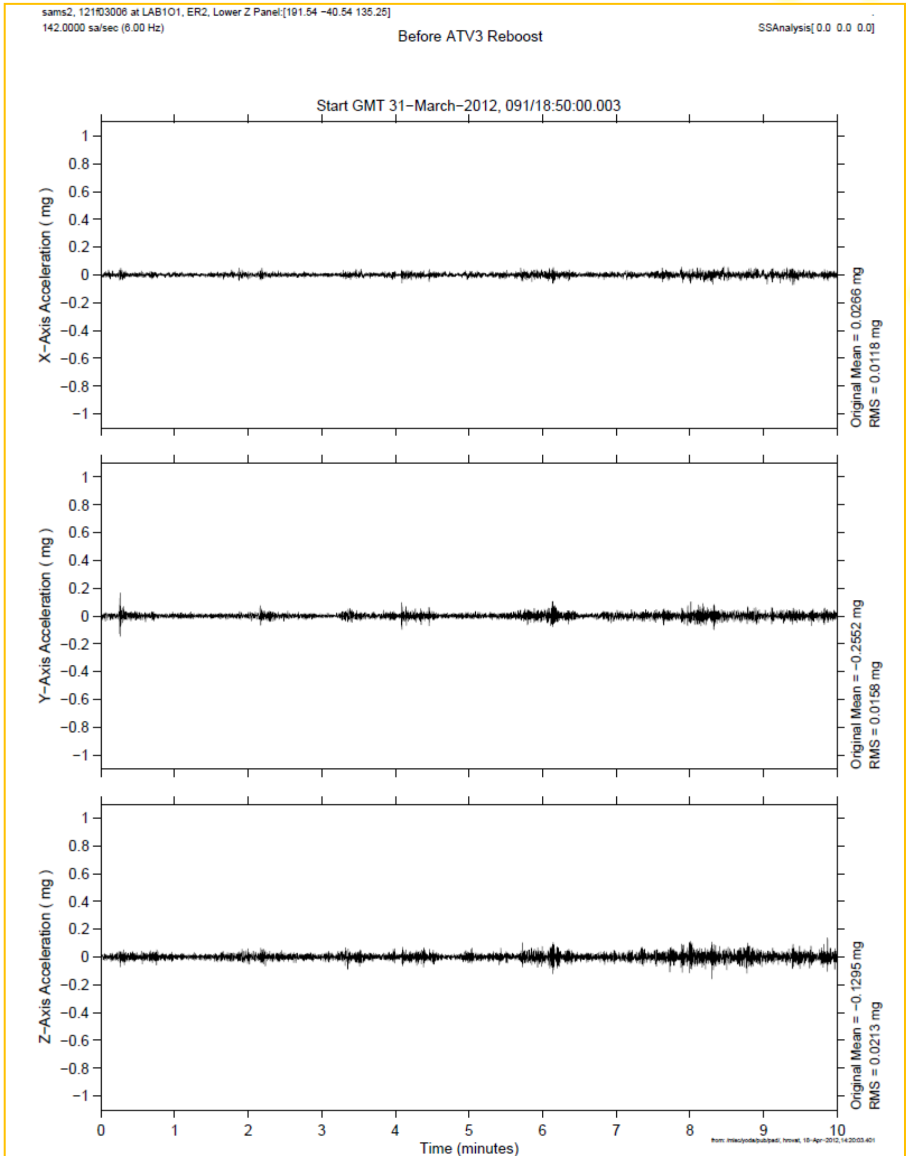


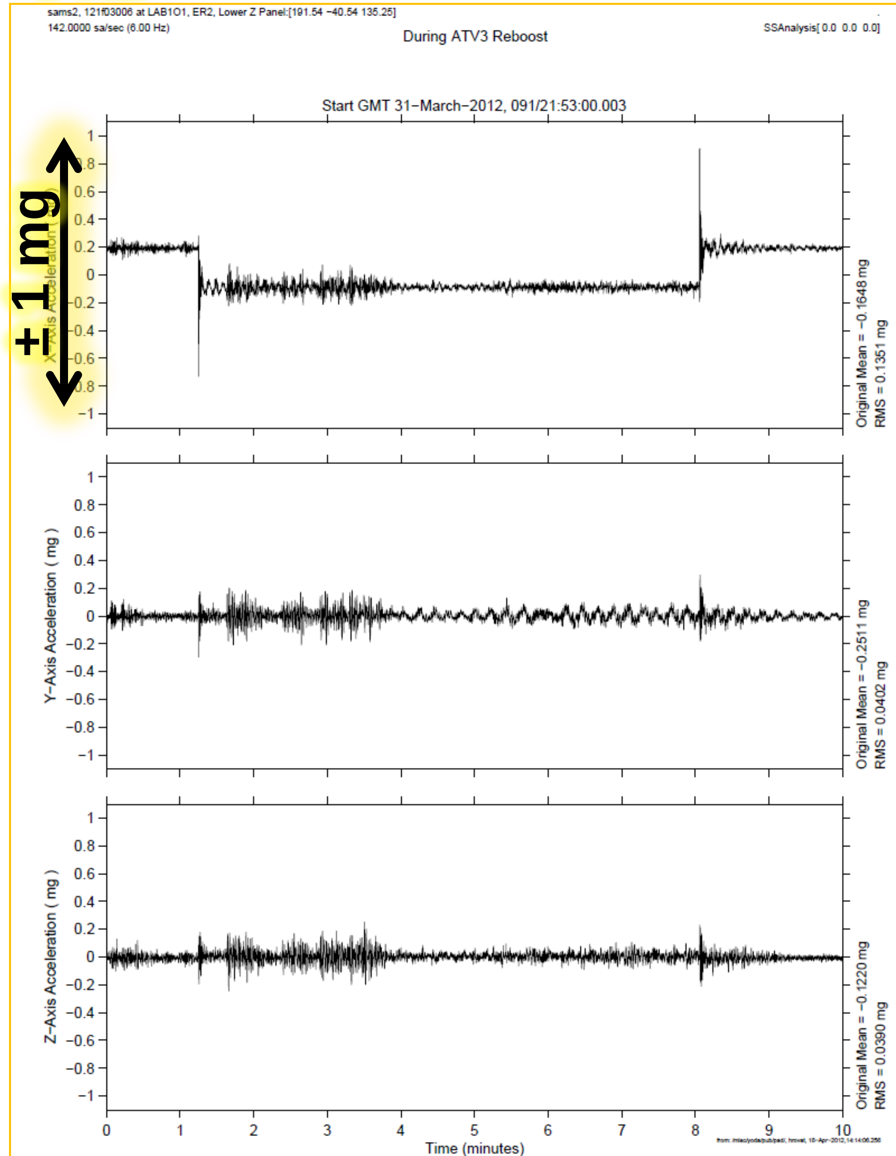
before and after reboost look remarkably similar

National Aeronautics and Space Administration (NASA) Glenn Research Center

ATV3 Reboost GMT 31-Mar-2012

BEFORE **0 < f < 6 Hz** **DURING**



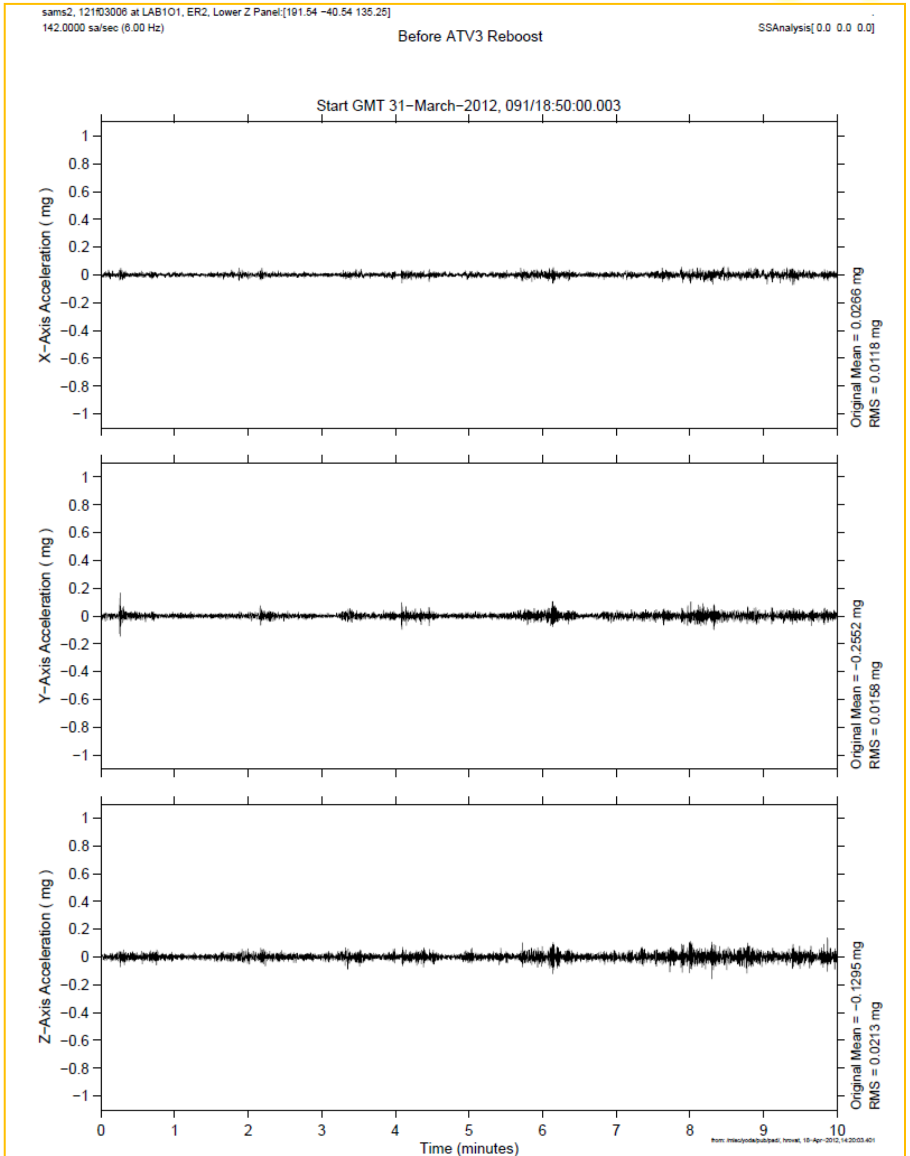


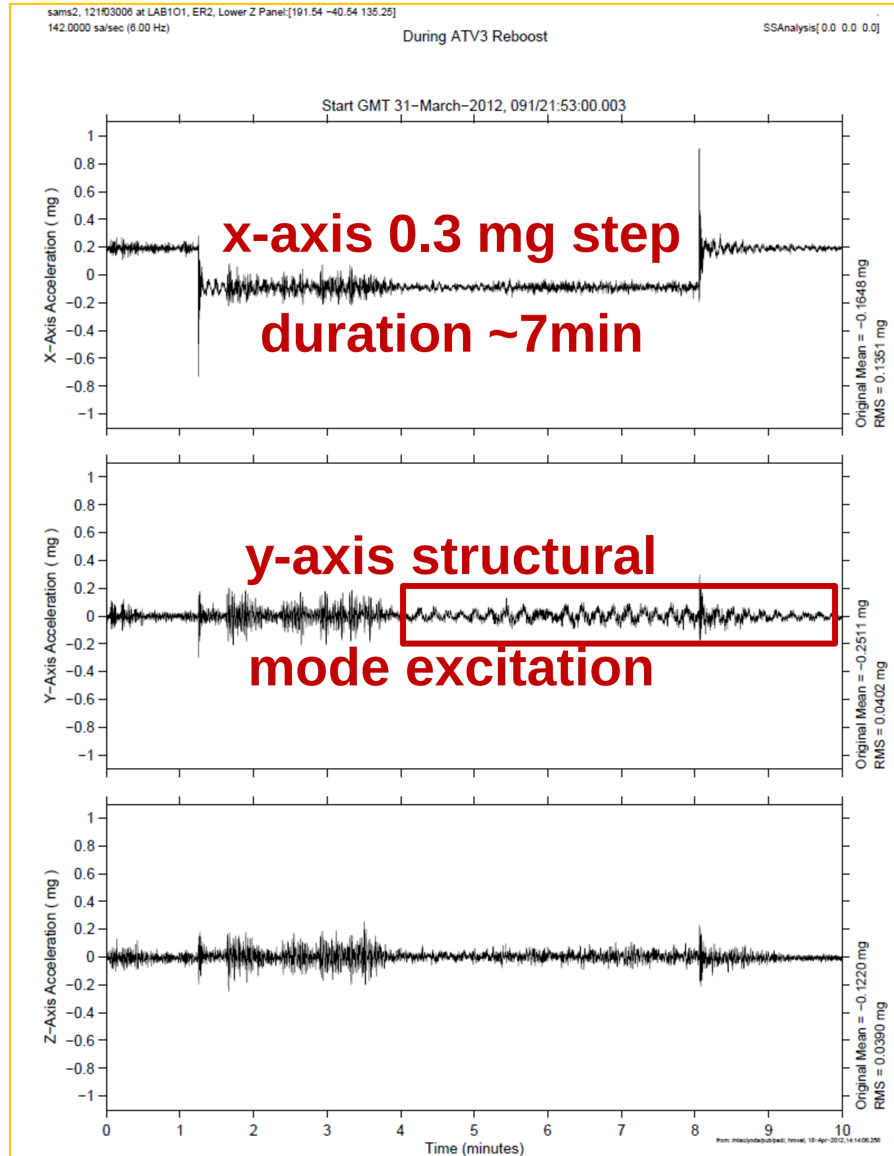
National Aeronautics and Space Administration (NASA) Glenn Research Center

ZIN Technologies

ATV3 Reboost GMT 31-Mar-2012

BEFORE **0 < f < 6 Hz** **DURING**





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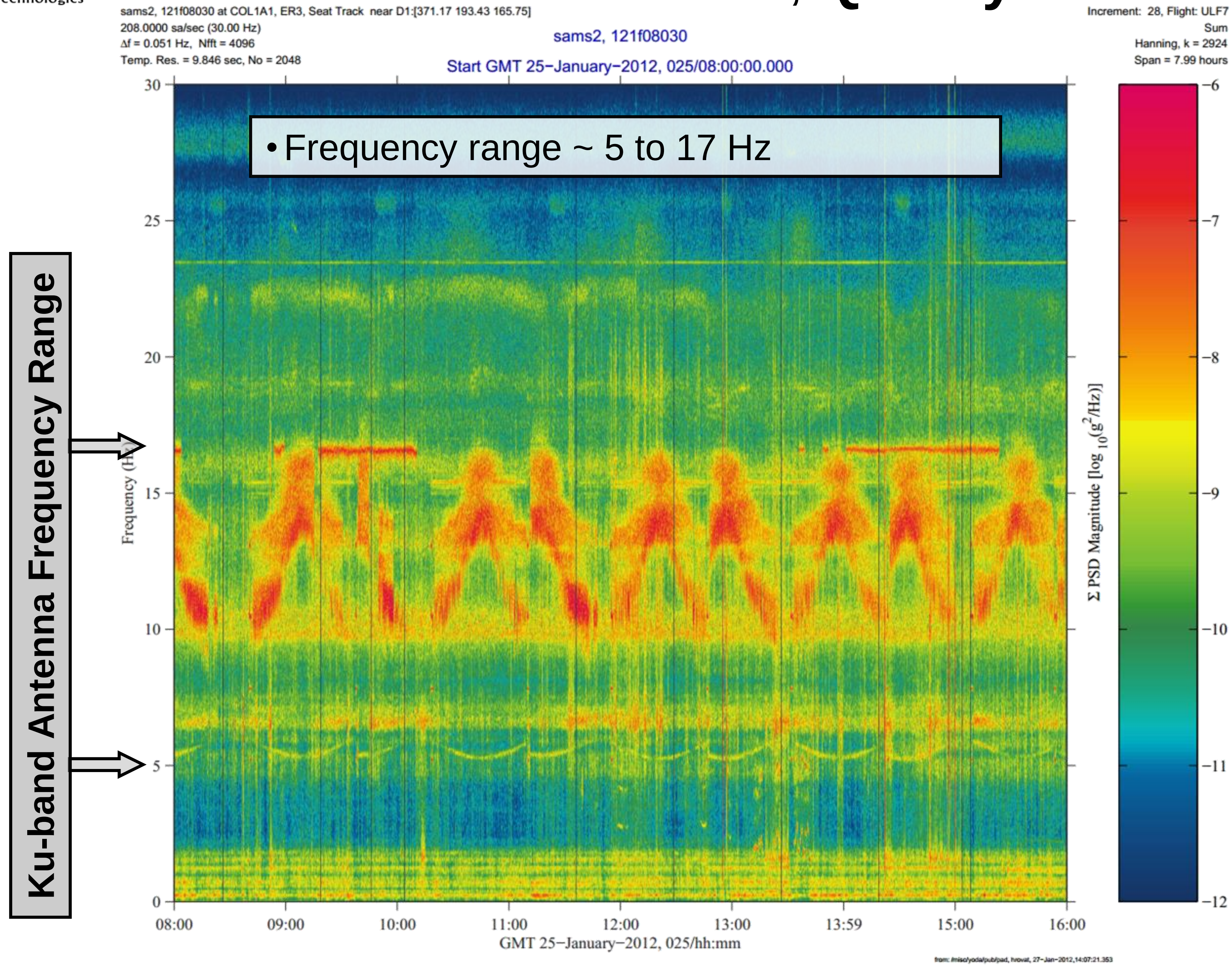
Outline

1. Capabilities and Services
2. Science Support and Customers
3. Timeline of Acceleration System Deployment
4. Current Sensor Locations on the ISS
5. Basics of the Microgravity Environment
6. Roadmaps for the Microgravity Environment
7. Brief Characterization of Some Disturbances
8. Reboosts
9. **Ku-Band Antenna**
10. When Should I Run My Experiment?
11. ARIS Attenuation During FIR Ops
12. Structural “Mode One”

Ku-Band Antenna, **Qualify**



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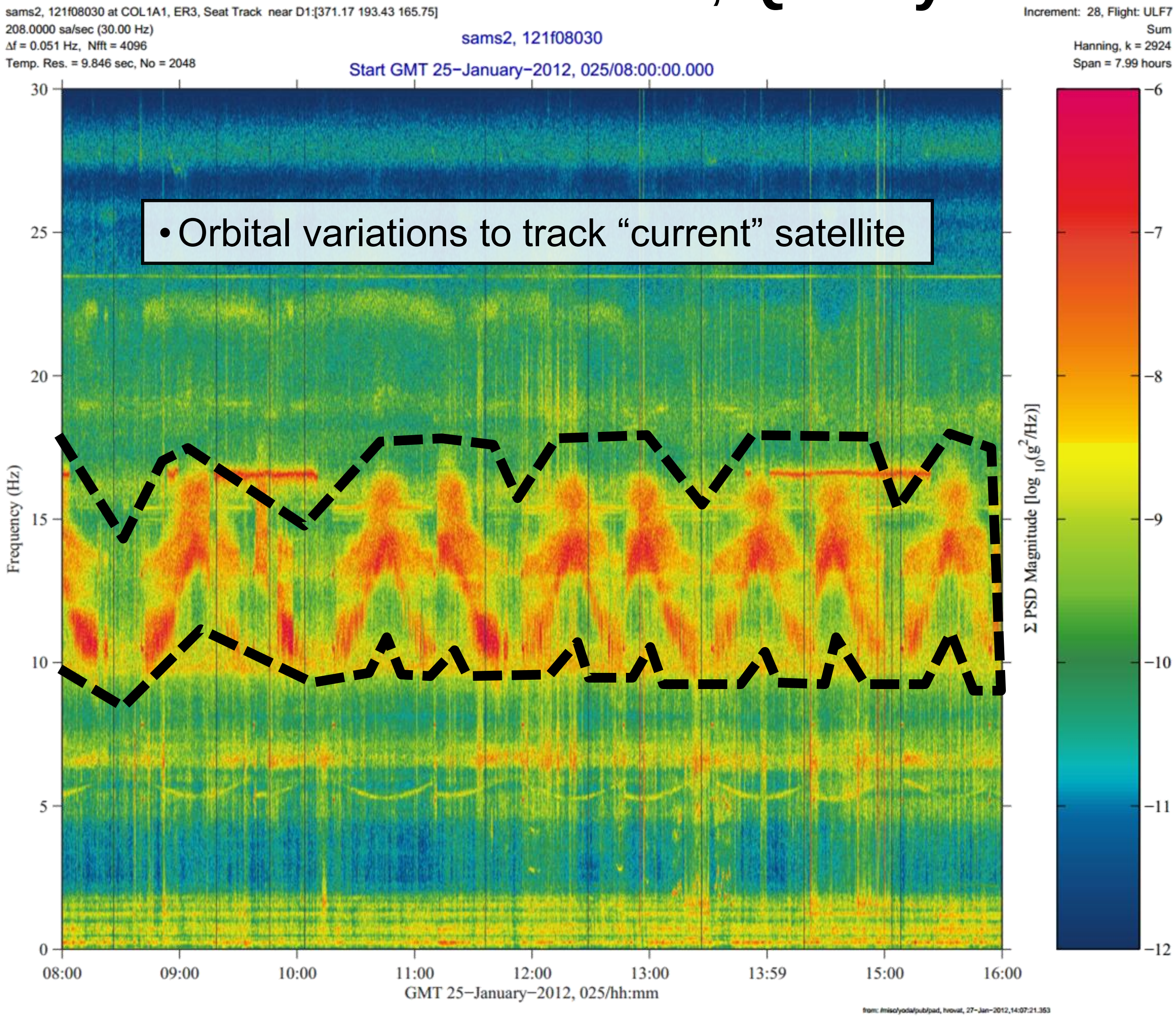
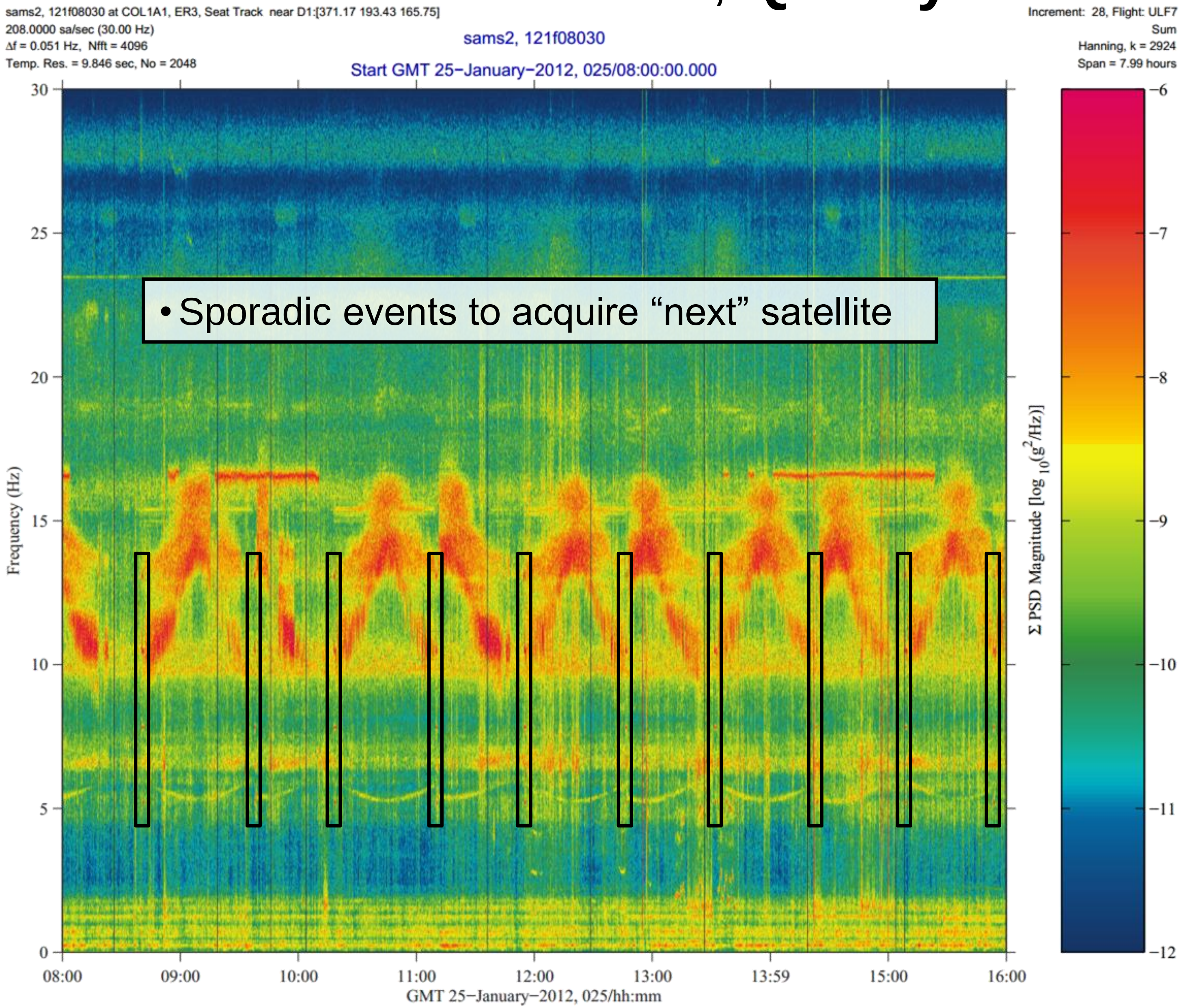
Ku-Band Antenna, **Qualify**



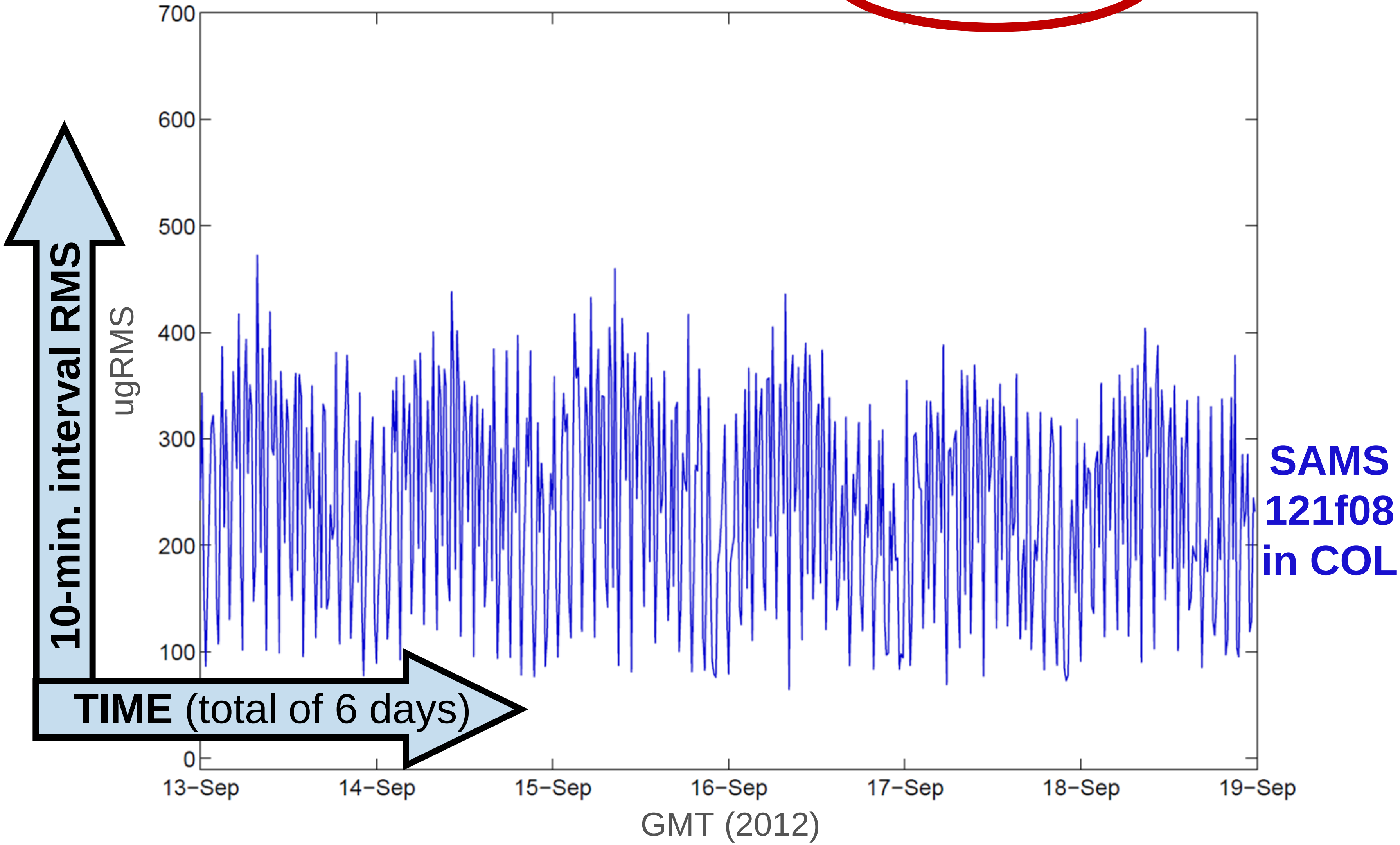
- Orbital variations to track “current” satellite

Ku-Band Antenna, **Qualify**



Ku-Band Antenna, **Quantify**

10-Minute Interval RMS, 5 < f < 17 Hz



Ku-Band Antenna, **Quantify**

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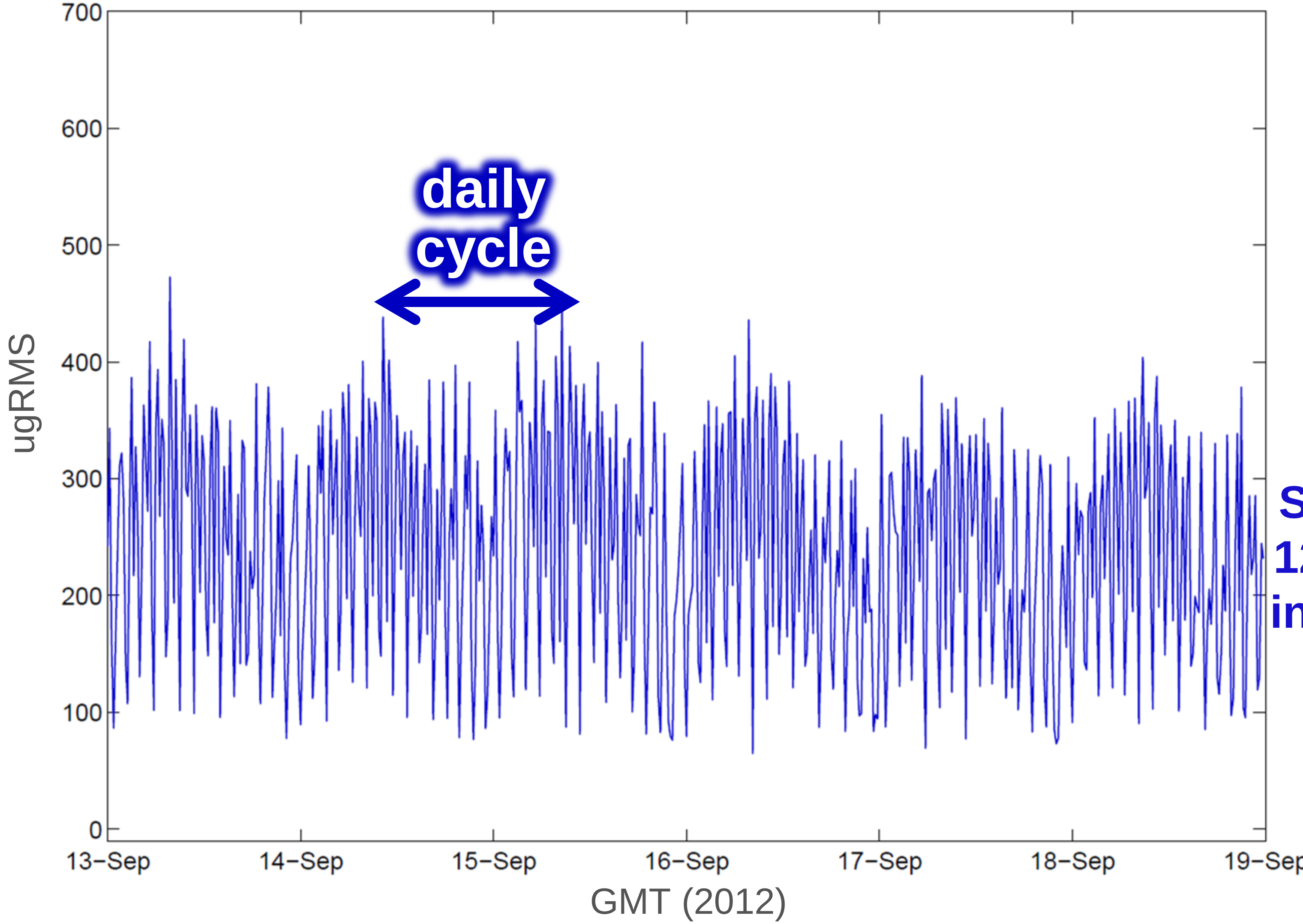


SAMS 121f08 in COL

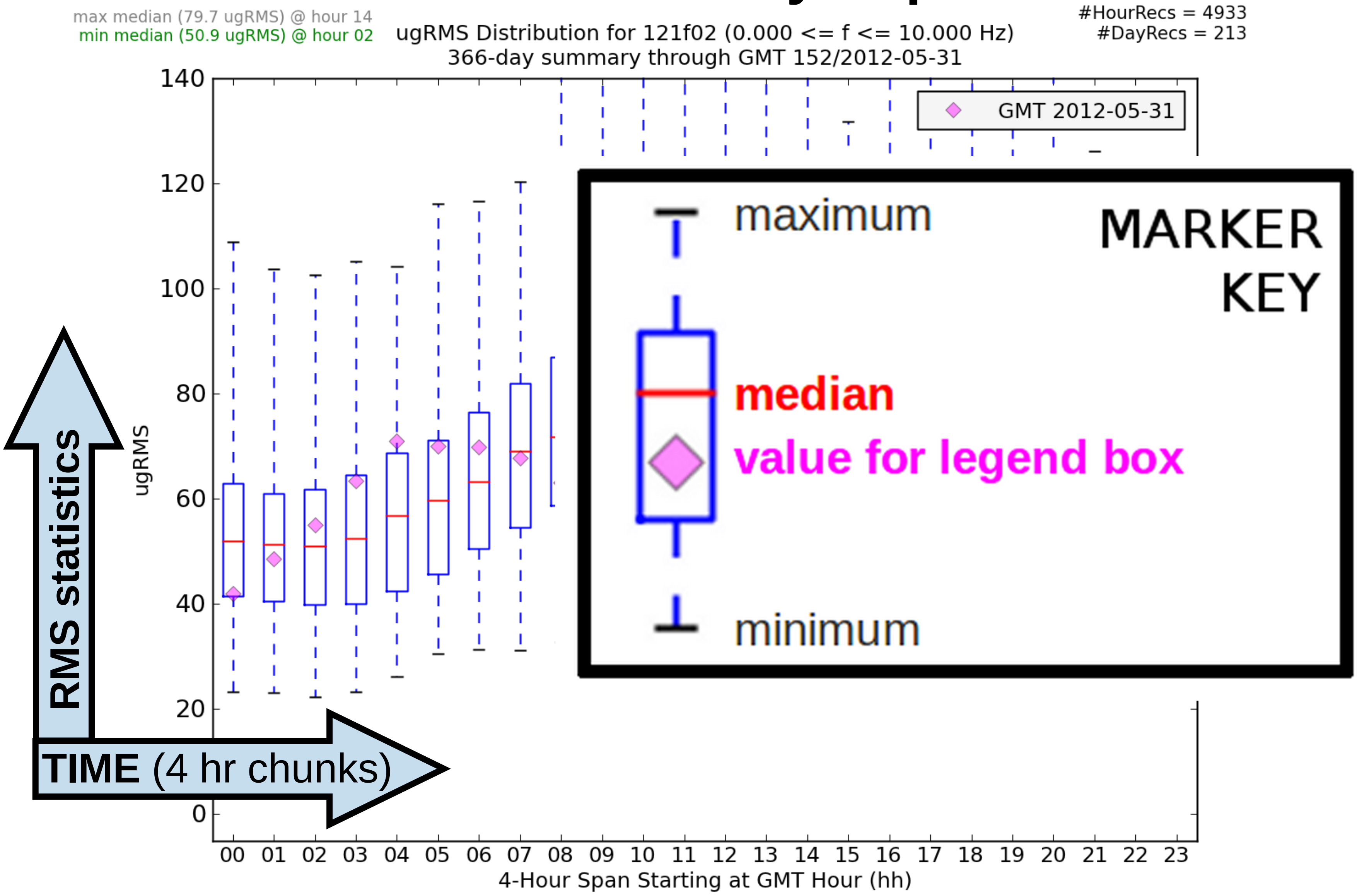
Ku-Band Antenna, **Quantify**

10-Minute Interval RMS, 5 < f < 17 Hz

SAMS SENSOR	LOCATION	Median RMS (ug)
121f03	USL, ER2	83
121f05	JEM, ER4	105
121f08	COL, ER3	235

Outline

When Should I Run My Experiment?



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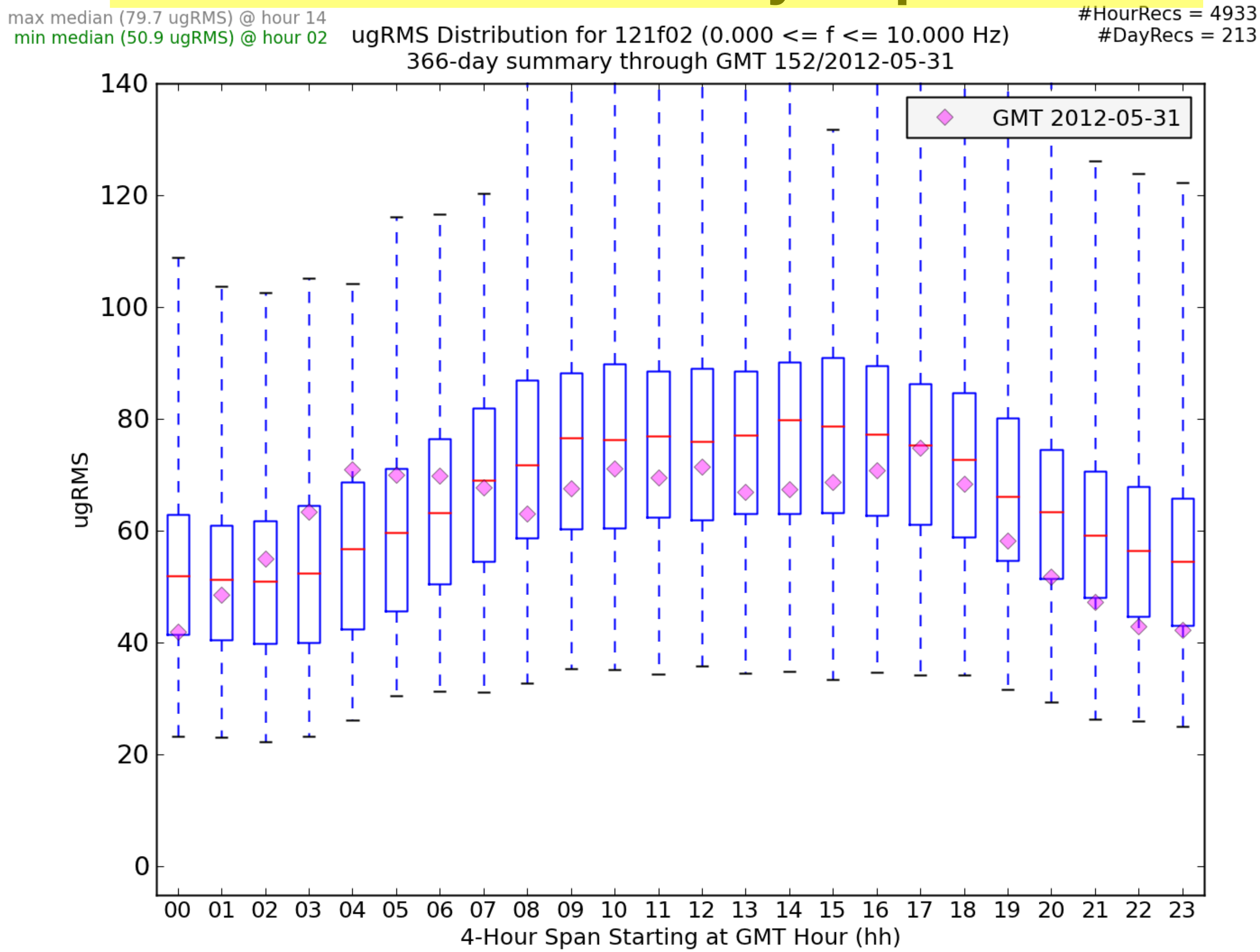
When Should I Run My Experiment?



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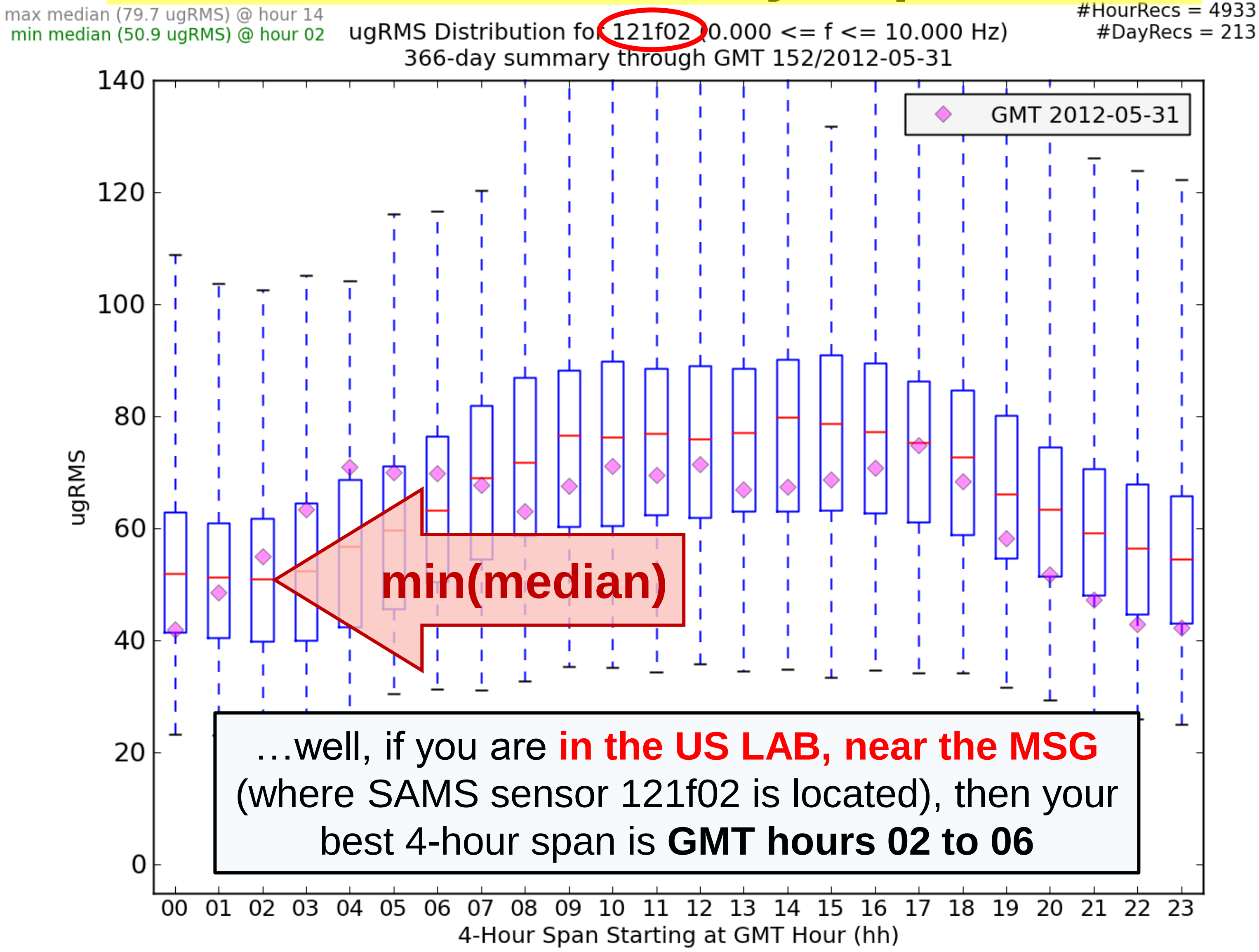
When Should I Run My Experiment?



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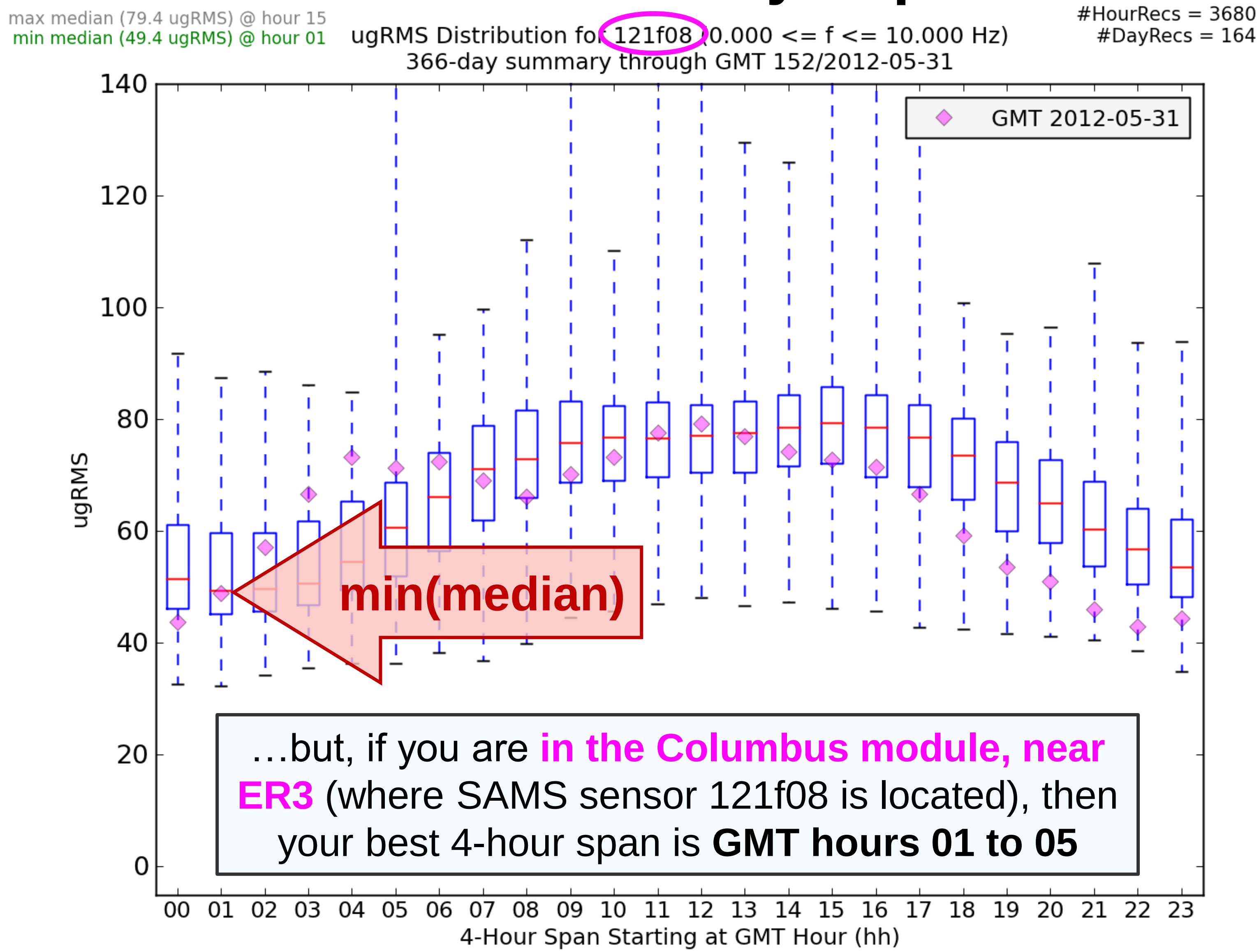

…but, if you are **in the Columbus module, near ER3** (where SAMS sensor 121f08 is located), then your best 4-hour span is **GMT hours 01 to 05**

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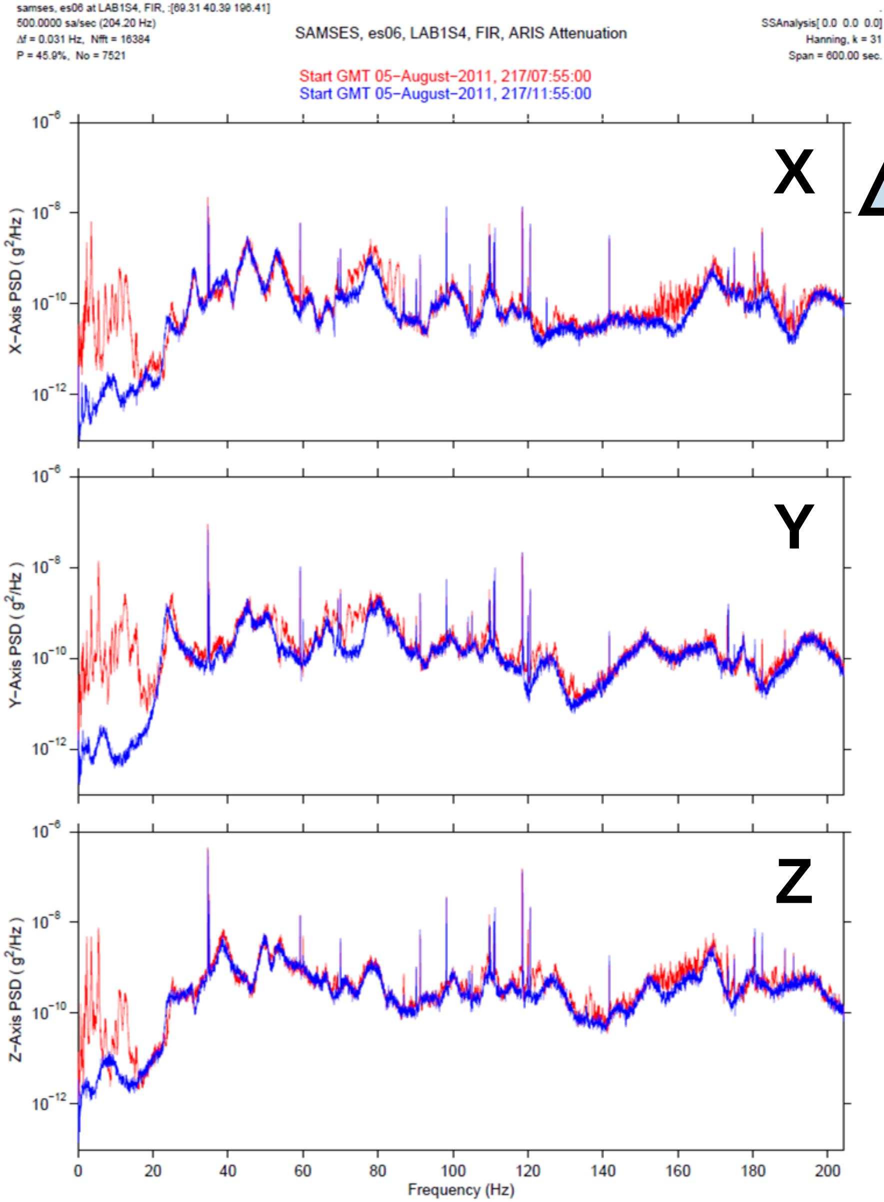
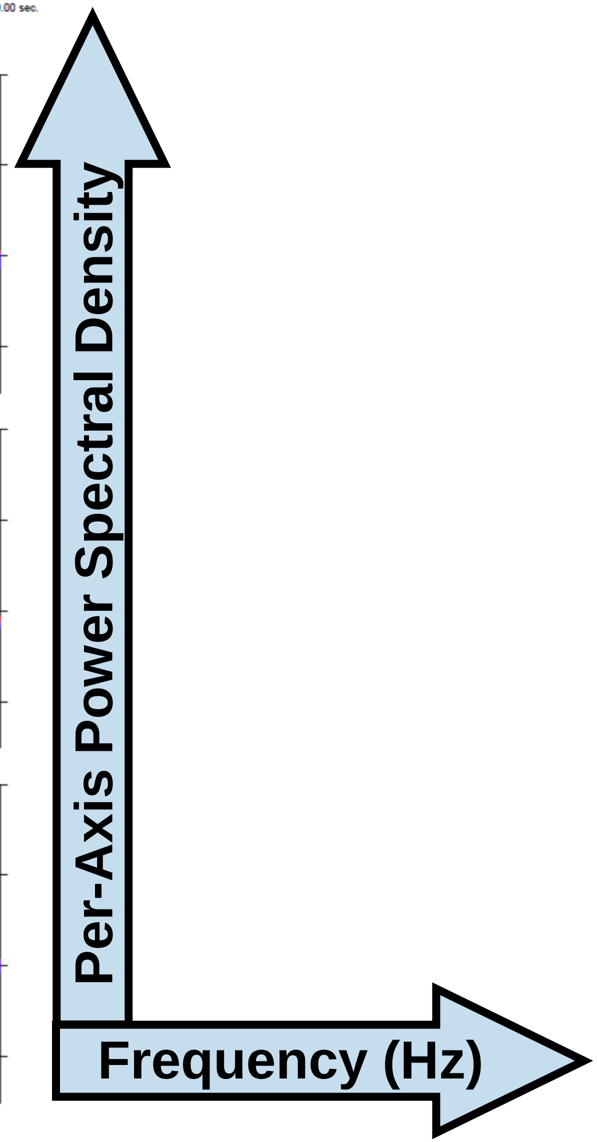
Outline

ARIS Attenuation During FIR Ops





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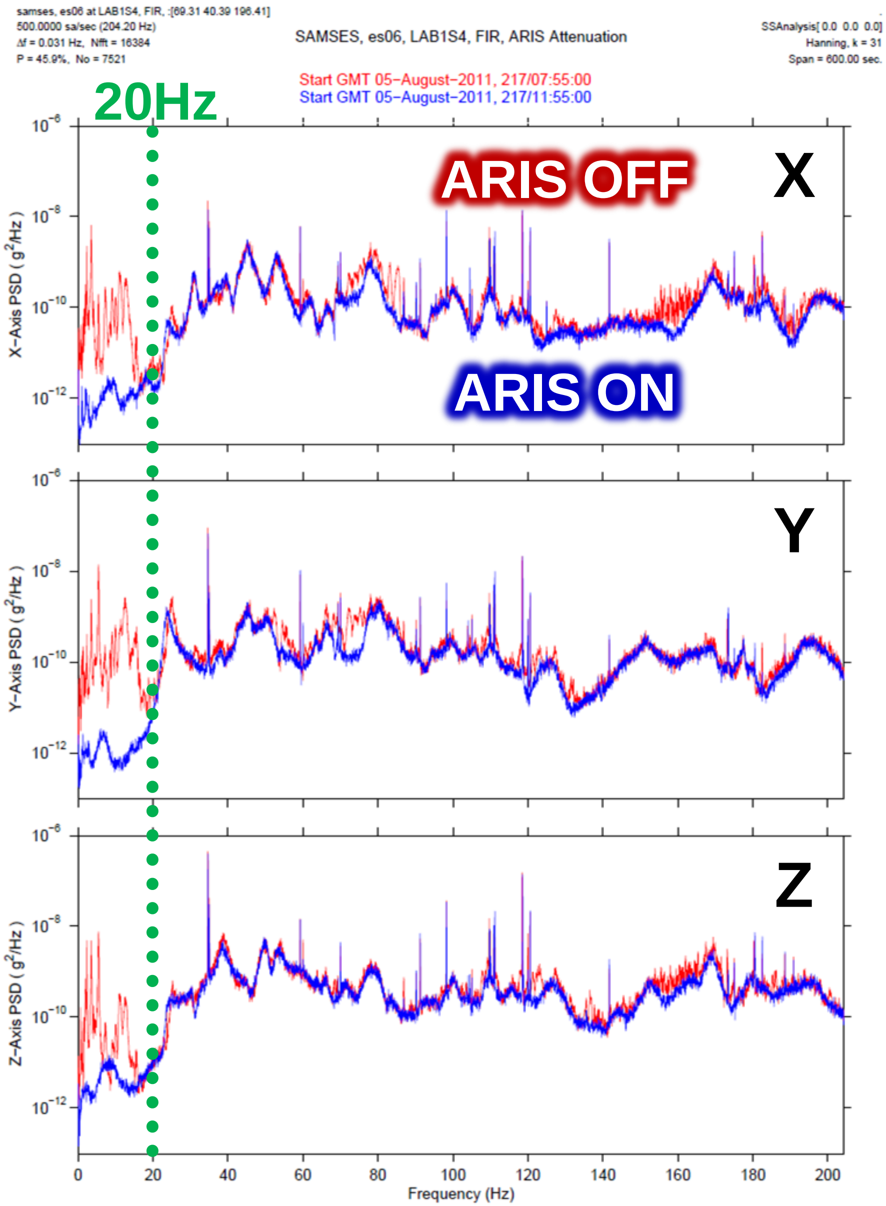
ARIS Attenuation During FIR Ops



Frequency Range (Hz)	GMT	RMS (ug) ARIS OFF	RMS (ug) ARIS ON
[0.01-20)	02-Aug-2012	105	9
	05-Aug-2012	96	12
[20-200)	02-Aug-2012	486	479
	05-Aug-2012	480	469

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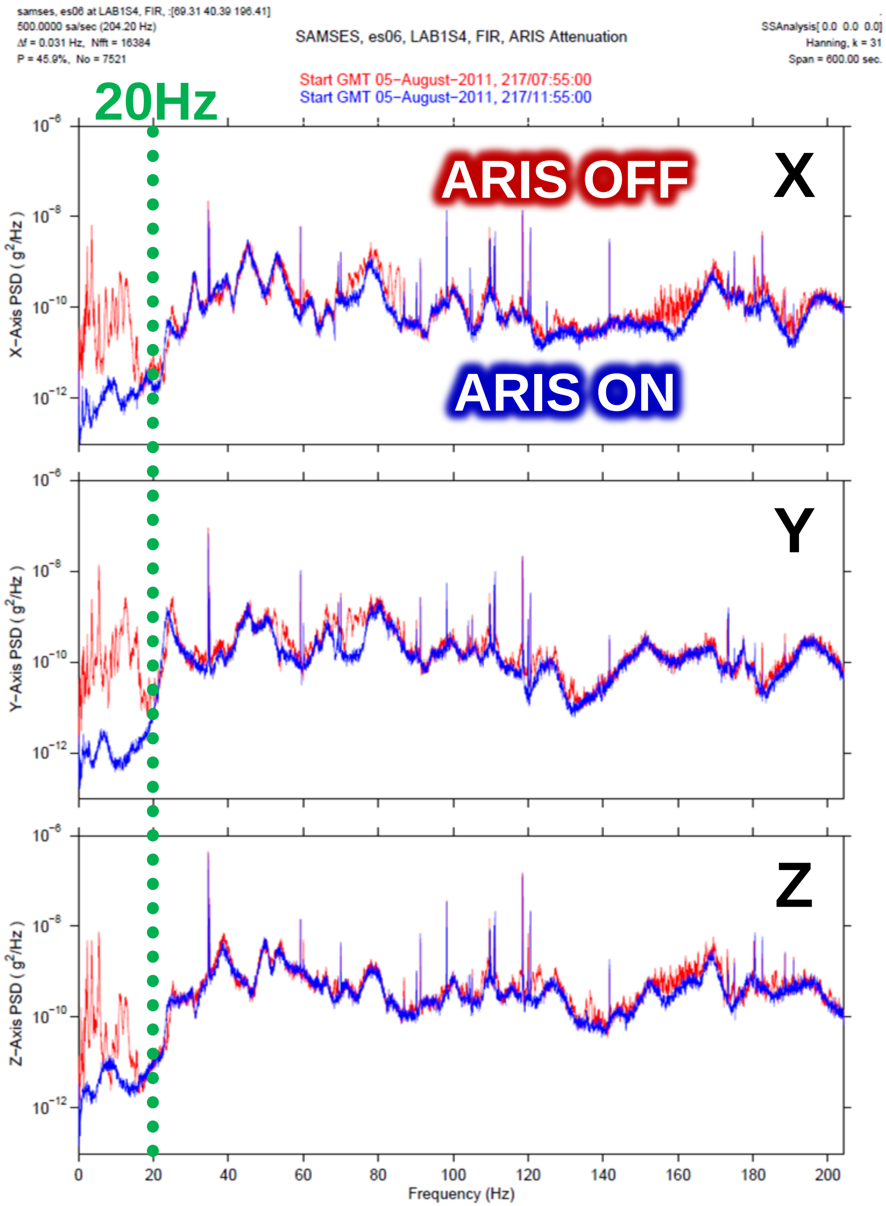
ARIS Attenuation During FIR Ops



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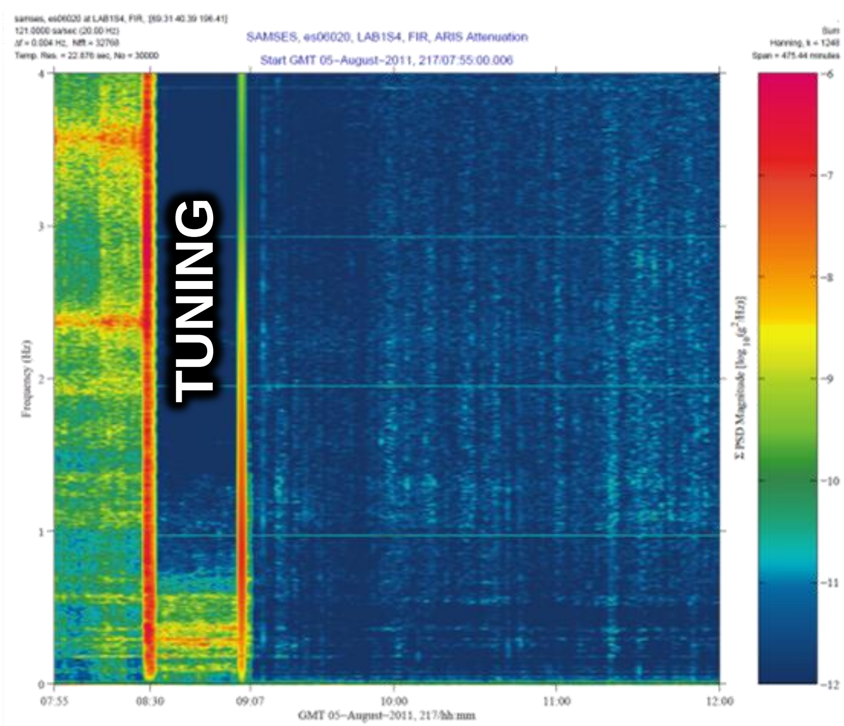

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12. **Structural "Mode One"**

“Mode One” – First Mode of Main Truss

In general, for **structural mode regime below 3 Hz**:

- is excited by crew activity and impulsive events
- RMS levels are nominally:
  - ~ 30 ugRMS for USL
  - ~ 40 ugRMS for COL and JEM

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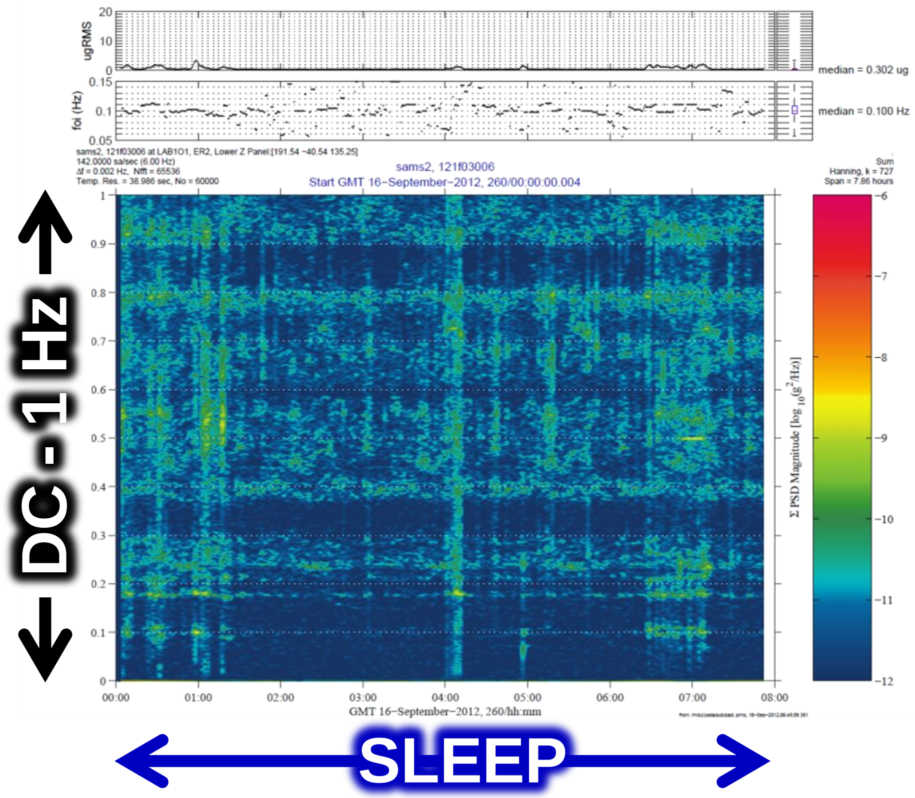

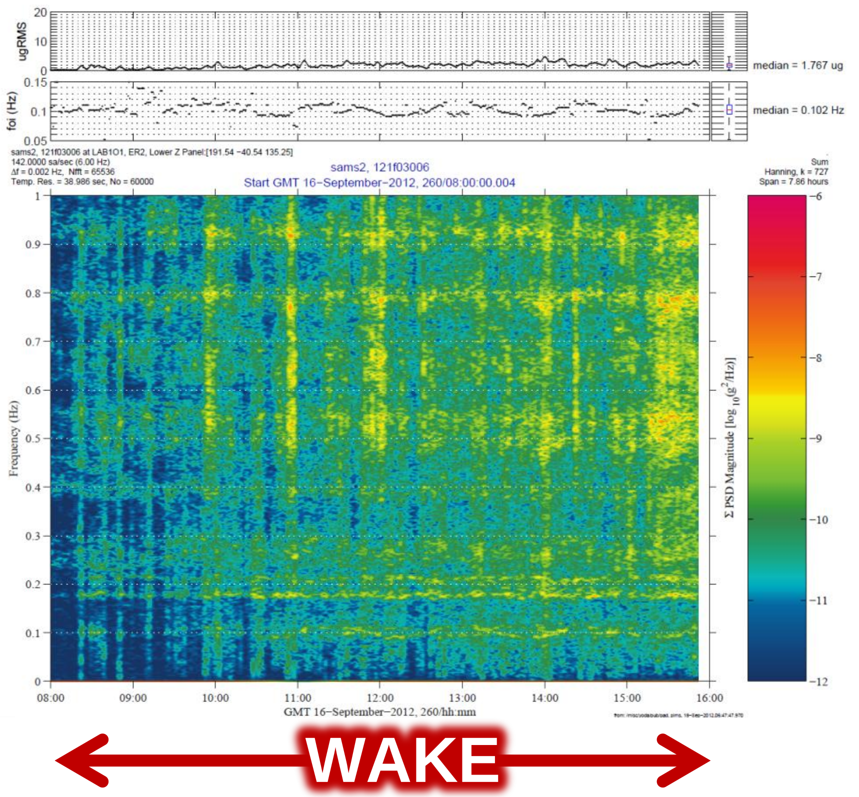

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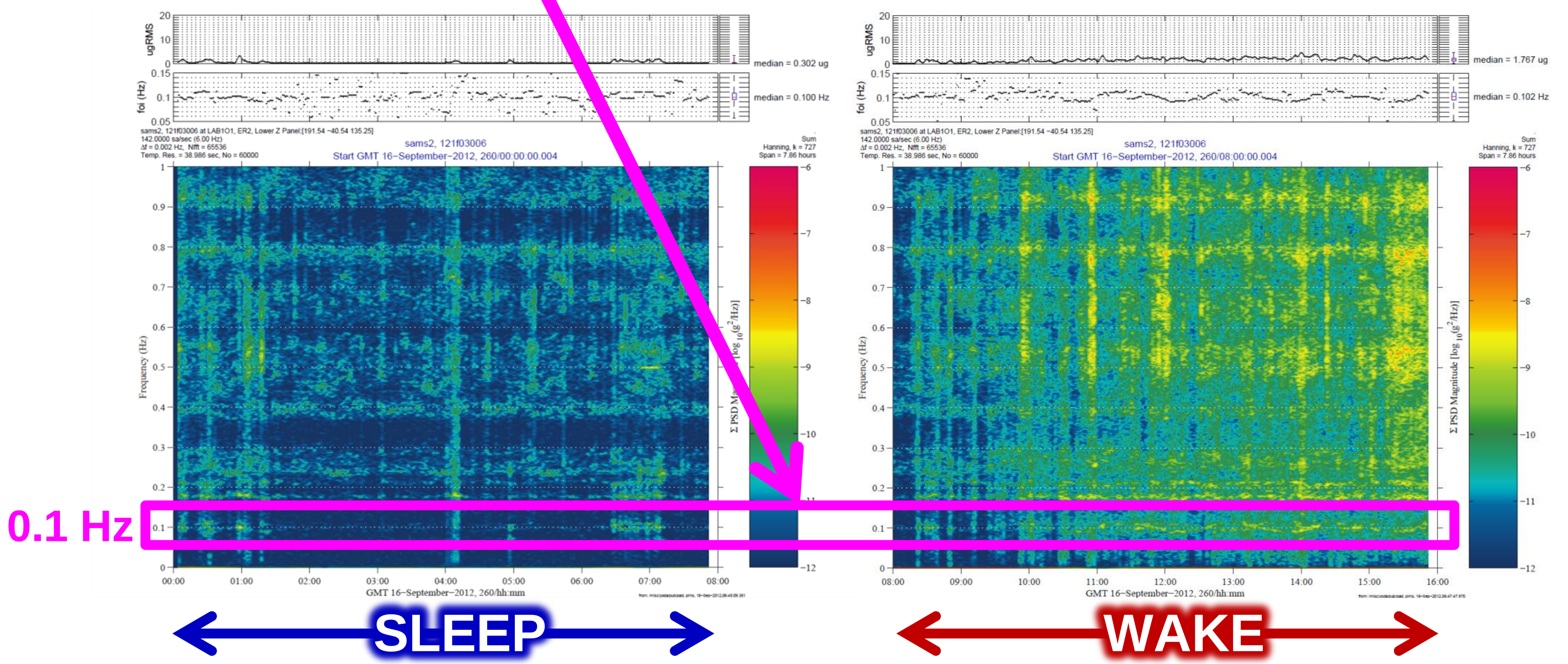

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“Mode One” – First Mode of Main Truss

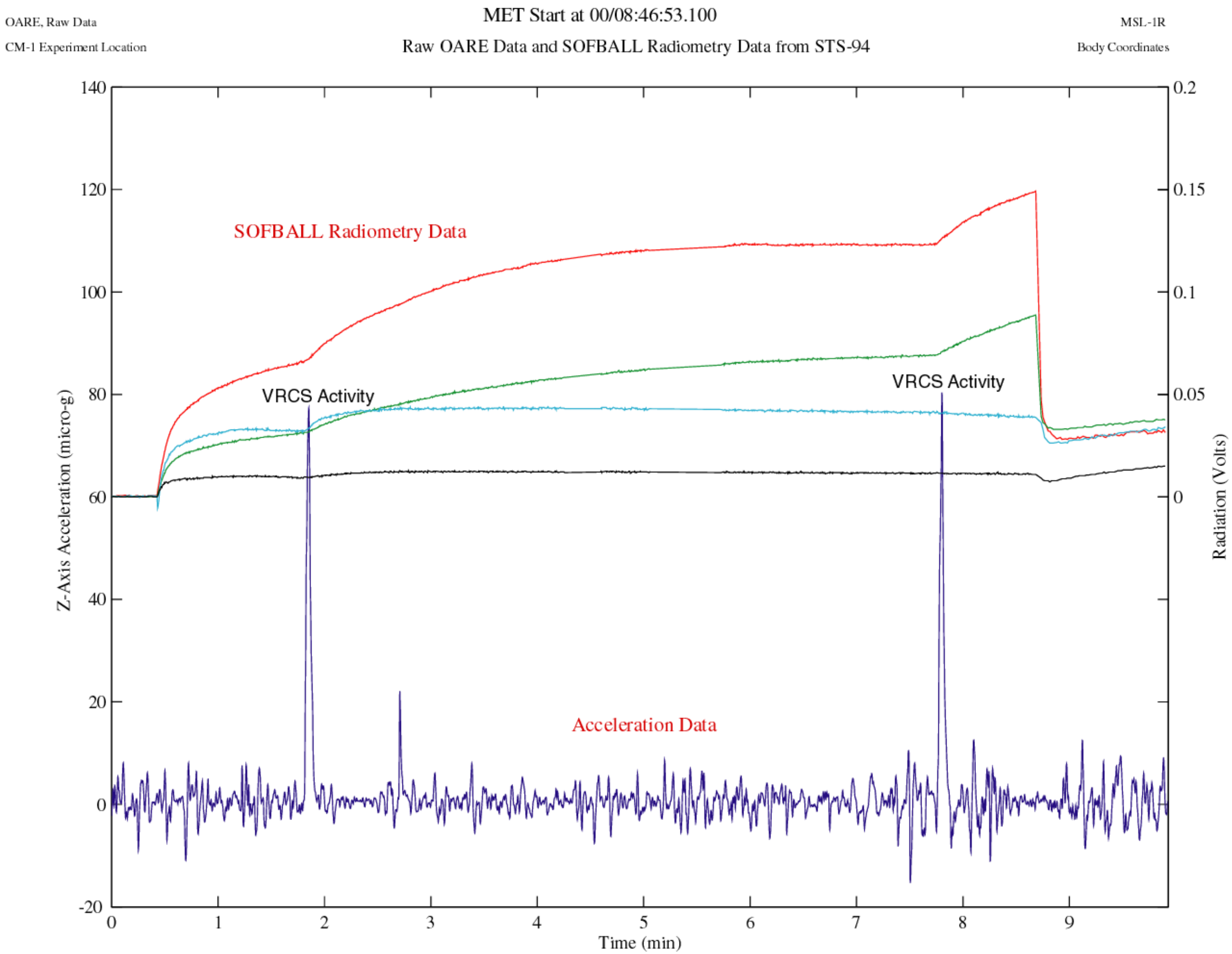
Mode One:

- is monitored daily for structural integrity & off-nominal impacts
- in Sept. 2012, nominal RMS levels were:
  - < 2 ugRMS for USL
  - < 3 ugRMS for COL and JEM

Backup Slides

- Impacts on Shuttle Microgravity Science
- Shuttle Crew Exercise Comparison
- ISS Crew Exercise
- Historical Look at Sensor Locations on the ISS
- System Characteristics

Impacts on Shuttle Microgravity Science



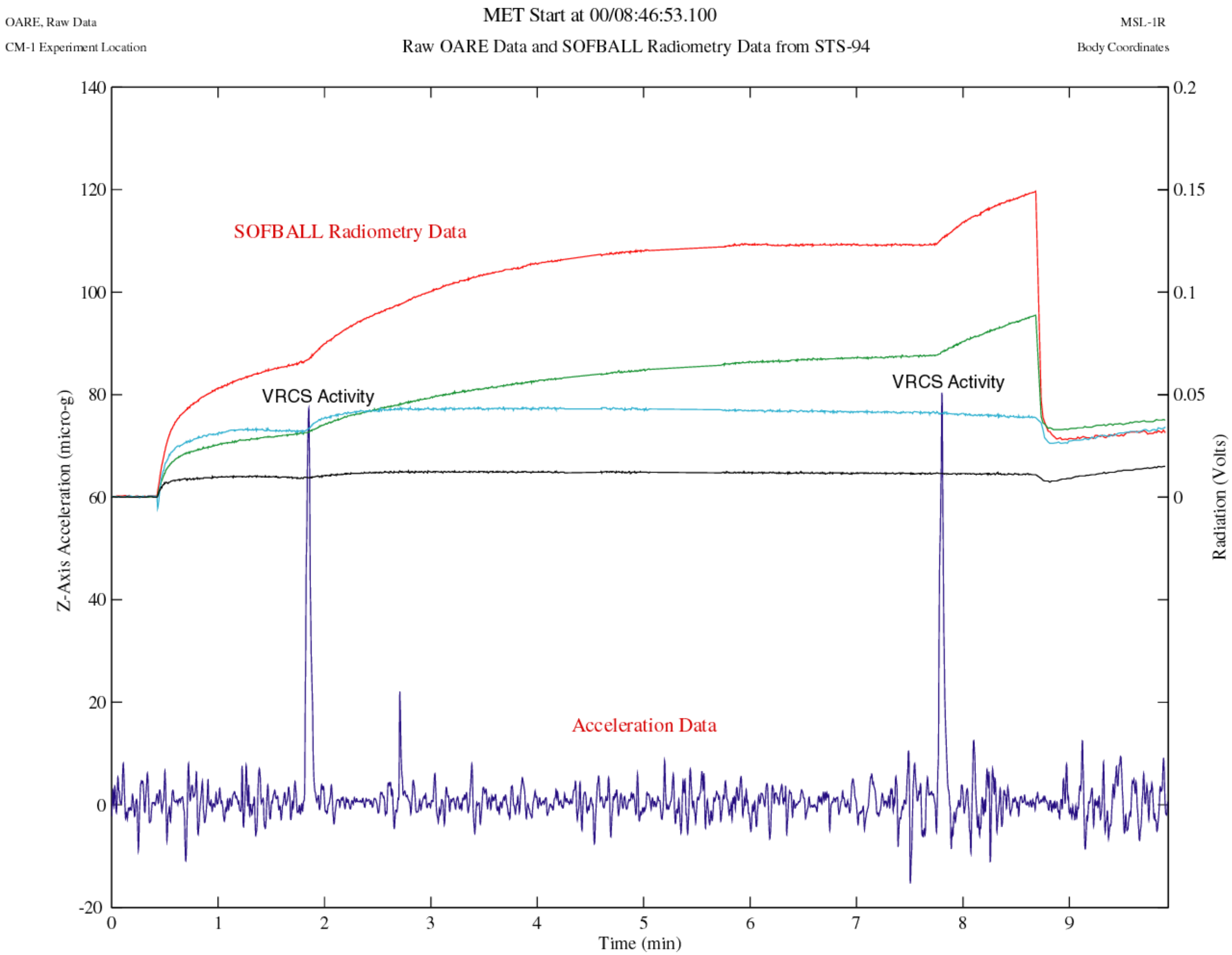
Near real-time support to investigators…

Example:
SOFBALL experiment sensitive to impulsive disturbances during execution of test points.

PIMS:
Correlate OARE data with SOFBALL science data.

Results:
SOFBALL team had justification needed to request periods of STS "free drift" (no thrusters) in order to conduct their experiment.

Impacts on Shuttle Microgravity Science



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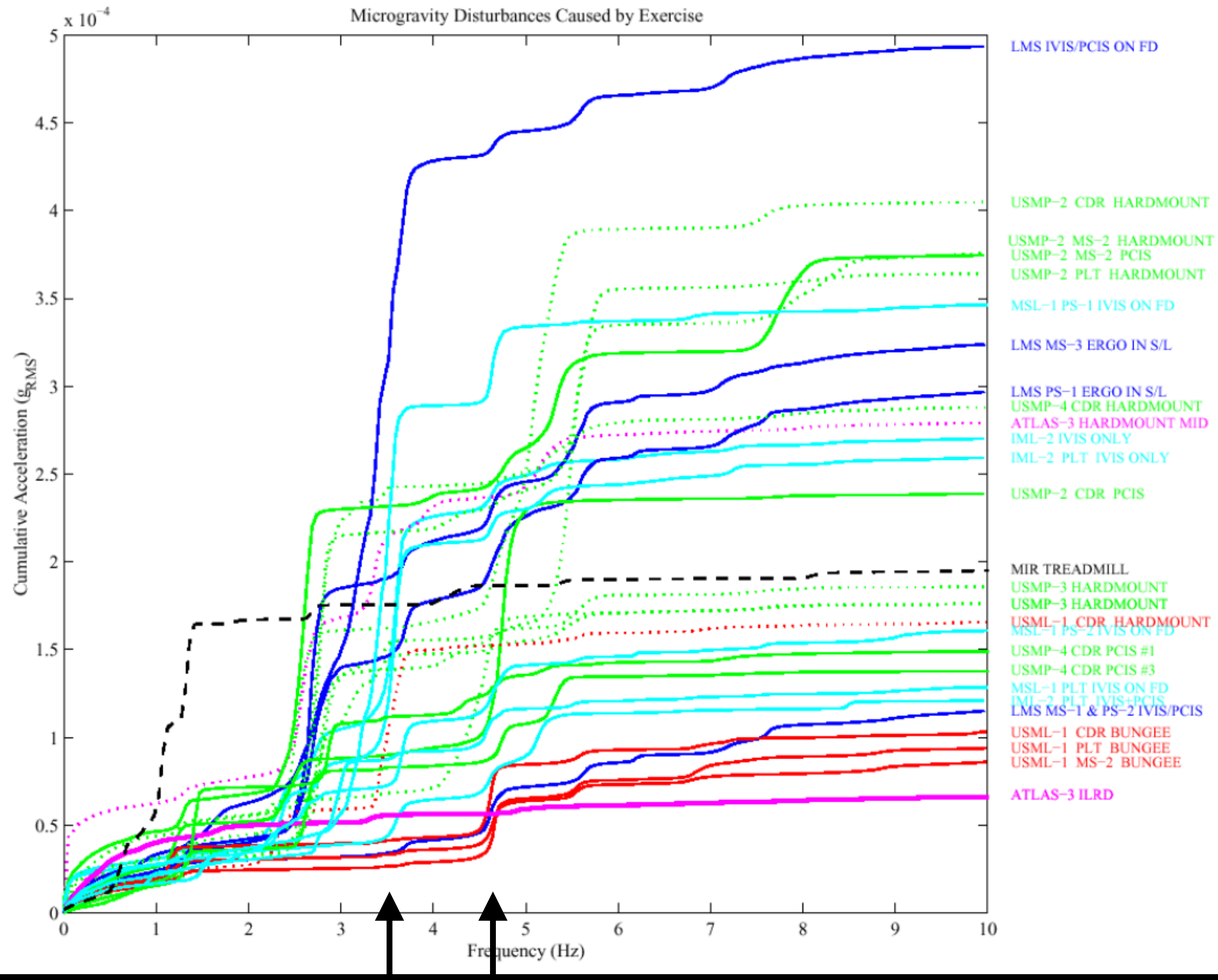
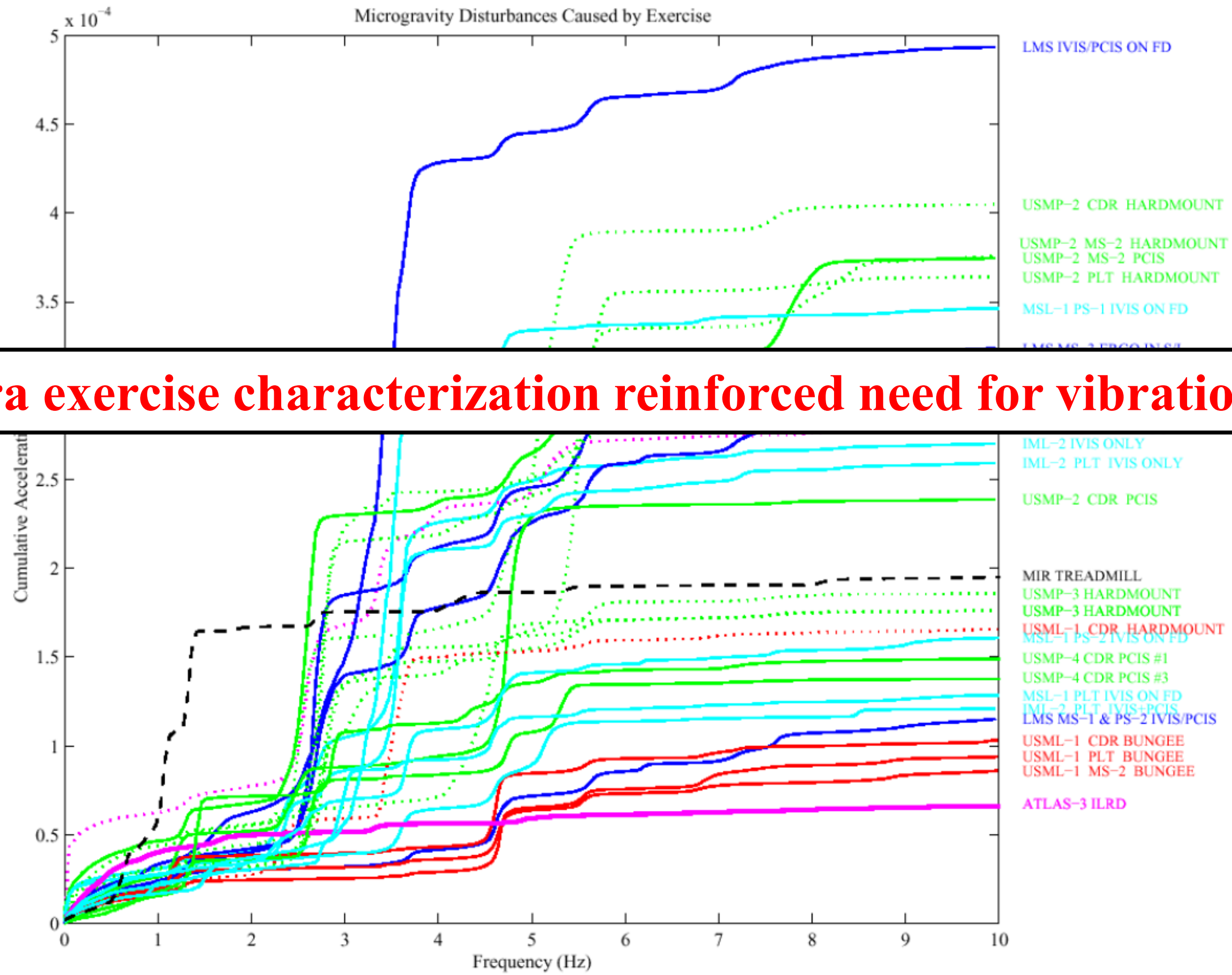
Shuttle Crew Exercise Comparison



2 spectral peaks arise from shoulder sway & pedaling rate with excitation of Shuttle structural modes @ 3.5 and 4.8 Hz

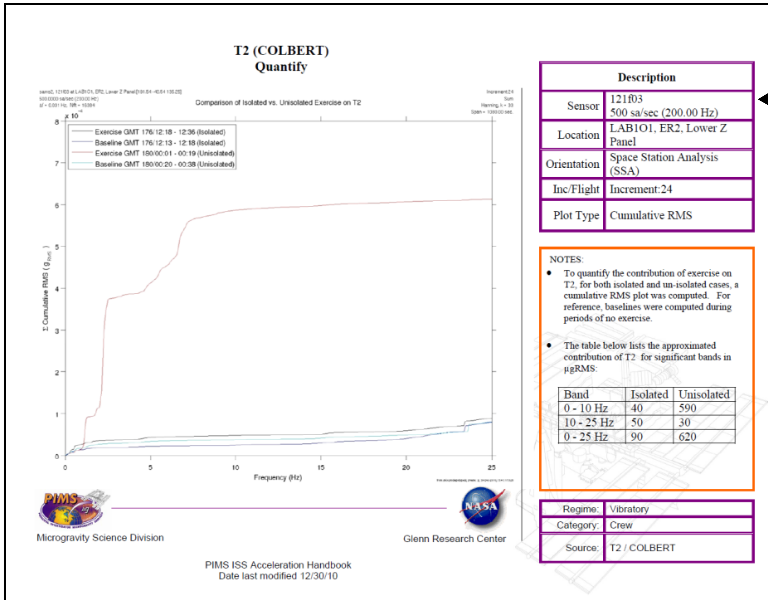
Shuttle Crew Exercise Comparison



Shuttle era exercise characterization reinforced need for vibration isolation

ISS Crew Exercise

The Combined Operational Load Bearing External Resistance Treadmill (**COLBERT**), technically named the Treadmill 2 (**T2**) derived from the Treadmill with Vibration Isolation Stabilization System (**TVIS**)



T2 (COLBERT)
Quantify

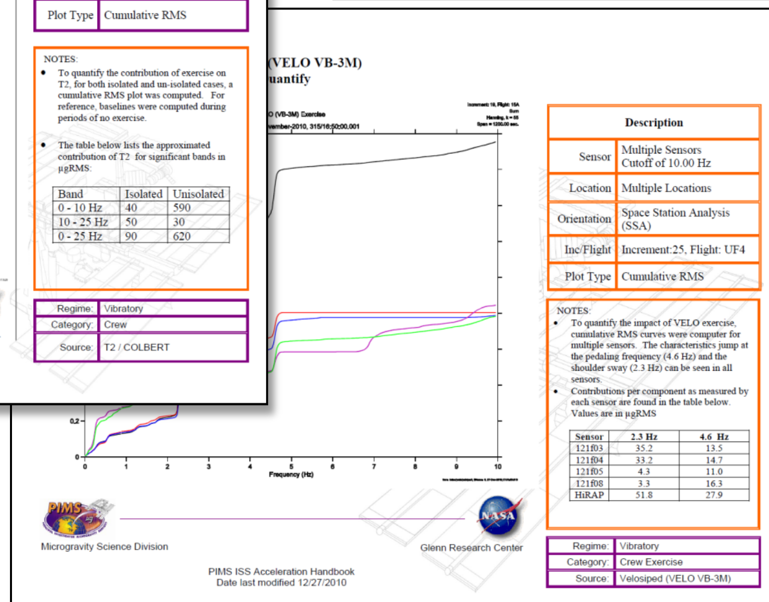
Description	
Sensor	121f03 500 sa/sec (200.00 Hz)
Location	LAB1O1, ER2, Lower Z Panel
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment:24
Plot Type	Cumulative RMS

NOTES:

- To quantify the contribution of exercise on T2, for both isolated and un-isolated cases, a cumulative RMS plot was computed. For reference, baselines were computed during periods of no exercise.
- The table below lists the approximate contribution of T2 for significant bands in μgRMS:

Band	Isolated	Unisolated
0 - 10 Hz	40	590
10 - 25 Hz	50	30
0 - 25 Hz	90	620

Regime:	Vibratory
Category:	Crew
Source:	T2 / COLBERT



(VELO VB-3M)
uantify

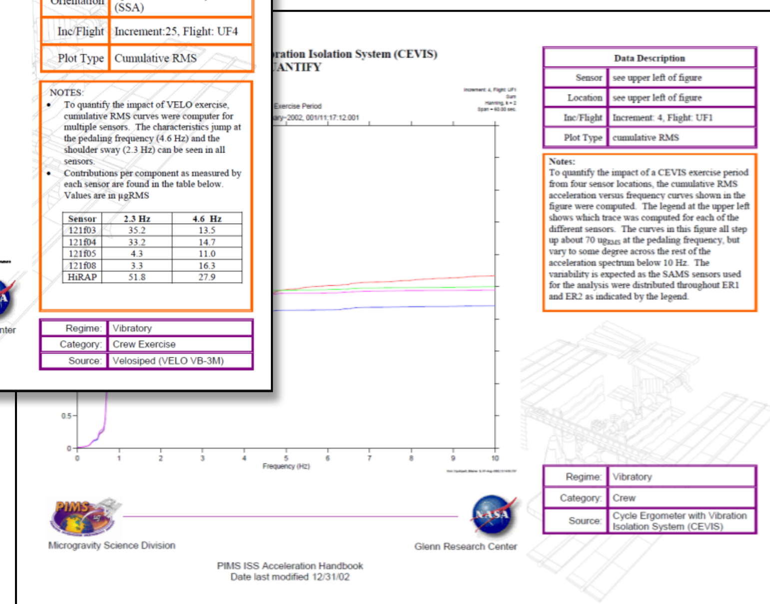
Description	
Sensor	Multiple Sensors Cutoff of 10.00 Hz
Location	Multiple Locations
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increment:25, Flight: UF4
Plot Type	Cumulative RMS

NOTES:

- To quantify the impact of VELO exercise, cumulative RMS curves were computer for multiple sensors. The characteristics jump at the pedaling frequency (4.6 Hz) and the shoulder sway (2.3 Hz) can be seen in all sensors.
- Contributions per component as measured by each sensor are found in the table below. Values are in μgRMS

Sensor	2.3 Hz	4.6 Hz
121f03	35.2	13.5
121f04	33.2	14.7
121f05	4.3	11.0
121f08	3.3	16.3
HiRAP	51.8	27.9

Regime:	Vibratory
Category:	Crew Exercise
Source:	Velosiped (VELO VB-3M)



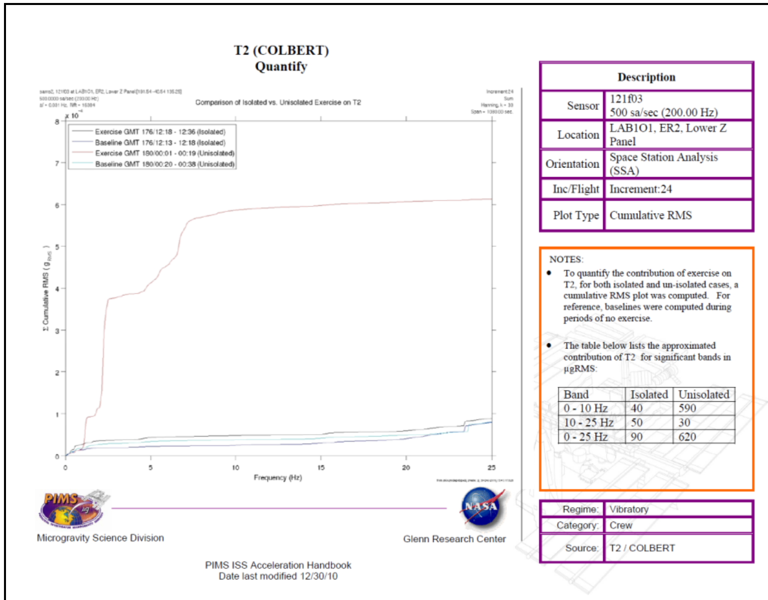
ration Isolation System (CEVIS)
ANTIFY

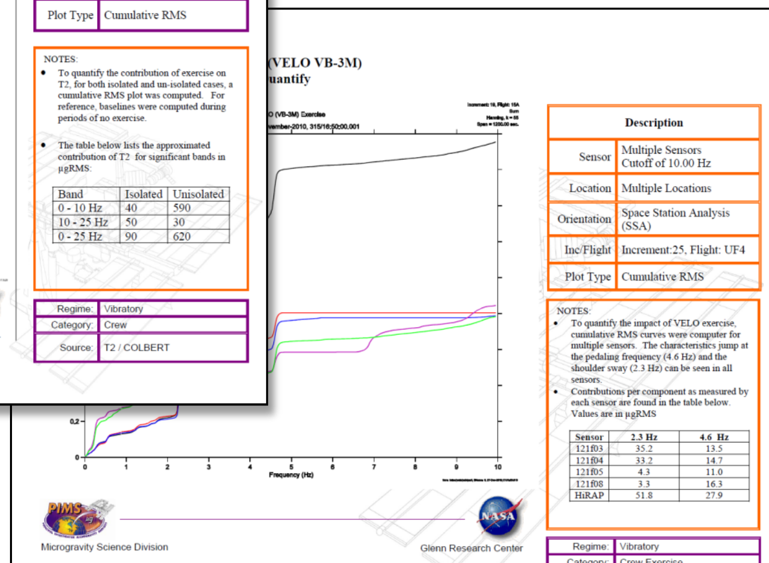
Data Description	
Sensor	see upper left of figure
Location	see upper left of figure
Inc/Flight	Increment: 4, Flight: UF1
Plot Type	cumulative RMS

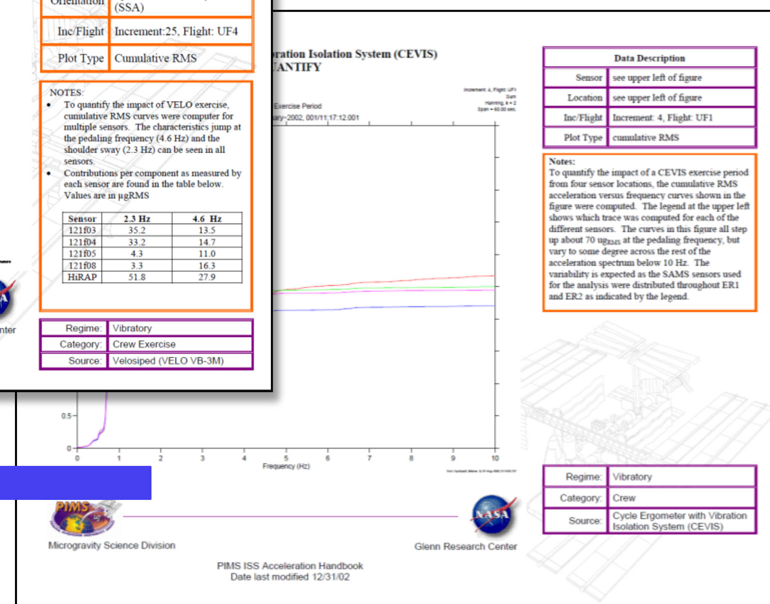
Notes:
To quantify the impact of a CEVIS exercise period from four sensor locations, the cumulative RMS acceleration versus frequency curves shown in the figure were computed. The legend at the upper left shows which trace was computed for each of the different sensors. The curves in this figure all step up about 70 ug_{RMS} at the pedaling frequency, but vary to some degree across the rest of the acceleration spectrum below 10 Hz. The variability is expected as the SAMS sensors used for the analysis were distributed throughout ER1 and ER2 as indicated by the legend.

Regime:	Vibratory
Category:	Crew
Source:	Cycle Ergometer with Vibration Isolation System (CEVIS)

ISS Crew Exercise







Equipment	Frequency (Hz)	ug_{RMS}
CEVIS	2.6	70
Velo	4.6	14
T2 (isolated)	<10	40
T2 (non-isolated)	<10	590

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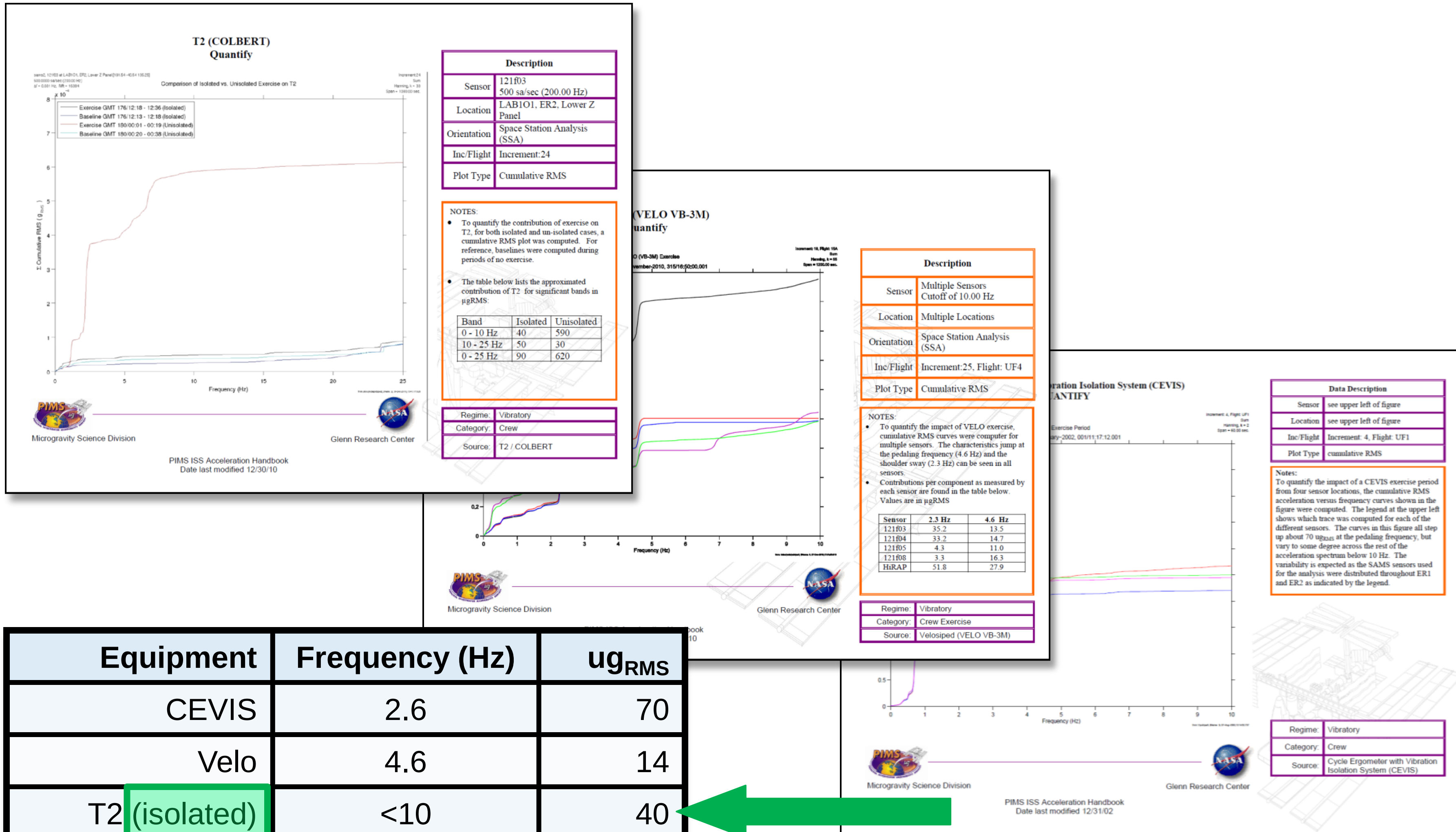
ISS Crew Exercise



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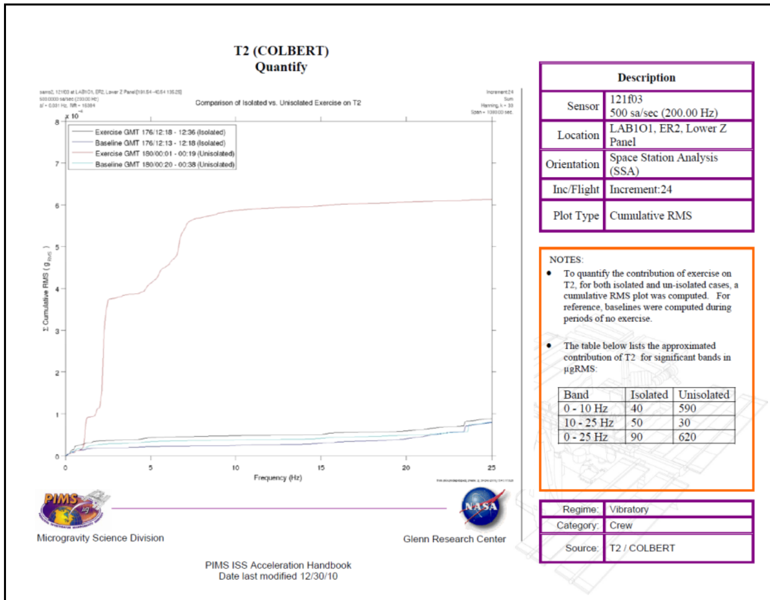
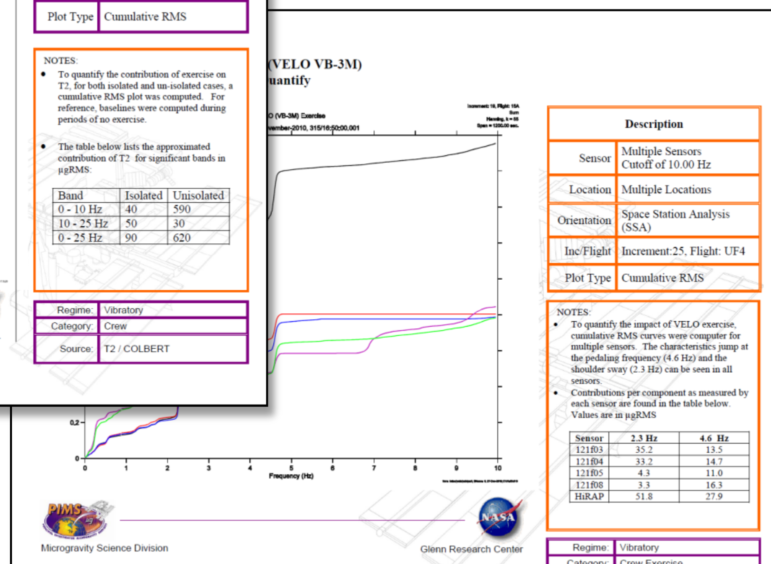
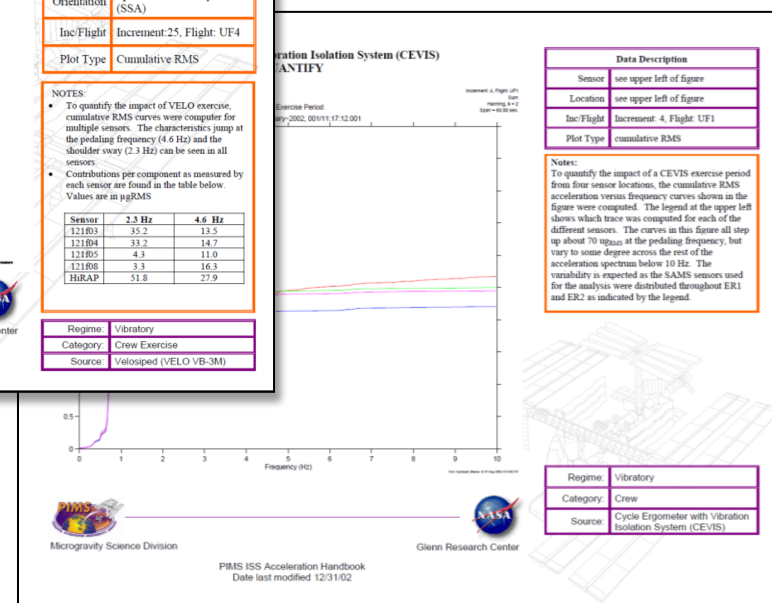
ISS Crew Exercise







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Historical Look at Sensor Locations on the ISS

Collectively, SAMS & MAMS Sensors Have Been Mounted in 21 Unique Locations

	system	coord_name	location_name	r_orient	p_orient	y_orient	x_location	y_location	z_location
Current	**MAMS**	**hirap**	**LAB1O2, ER1, Lockers 3,4**	**180**	**0**	**0**	**138.68**	**-16.18**	**142.35**
	MAMS	**ossraw**	**LAB1O2, ER1, Lockers 3,4**	**90**	**0**	**0**	**135.28**	**-10.68**	**132.12**
	SAMS	**121f02**	**LAB1S2, MSG, Upper Left Seat Track**	**0**	**0**	**90**	**161.95**	**40.39**	**157.64**
	SAMS	**121f03**	**LAB1O1, ER2, Lower Z Panel**	**0**	**30**	**-90**	**191.54**	**-40.54**	**135.25**
	SAMS	**121f04**	**LAB1O2, ER1, Lower Z Panel**	**0**	**30**	**-90**	**149.54**	**-40.54**	**135.25**
	SAMS	**121f05**	**JPM1F5, ER4, Drawer 2**	**-90**	**-90**	**0**	**466.8**	**-292.06**	**214.58**
	SAMS	**121f08**	**COL1A1, ER3, Seat Track near D1**	**0**	**0**	**180**	**371.17**	**193.43**	**165.75**
	SAMS	**es05**	**LAB1S3, CIR, Front Panel**	**180**	**0**	**90**	**116.81**	**40.39**	**192.76**
	SAMS	**es06**	**LAB1S4, FIR,**	**0**	**180**	**0**	**69.31**	**40.39**	**196.41**
Previous	SAMS	es08	COL1F2, MSG, Ceiling Plate Y1-C3 Y2-D3	0	90	-90	475.71	235.22	160.27
	SAMS	121f02	LAB1P3, CEVIS, Frame	0	0	-90	118.45	-38.36	170.57
	SAMS	121f02	LAB1O2, ER1, Drawer 1	-90	0	-90	128.73	-23.53	144.15
	SAMS	121f02	JPM1F3, TCQ, Lower Panel	180	-45	0	455.55	-227.69	229.07
	SAMS	121f02	COL1D3, Forward Foot of FWED	90	-45	-90	395.08	287.99	232.22
	SAMS	121f05	LAB1O1, ER2, Upper Z Panel	90	0	90	185.17	38.55	149.93
	SAMS	121f08	LAB1S3, MSG, Ceiling Plate A2-A3	-90	90	0	115.21	53.41	160.98
	SAMS	121f08	LAB1S3, MSG, Ceiling Plate D3-D2	90	90	0	87.99	55.19	160.98
	SAMS	121f08	COL1A1, ER3, B2 Panel	0	180	0	374.17	166.19	157.03
	SAMS	121f08	COL1O1, FSL, ODM Seat Track	0	90	0	434.37	183.25	147.01
	SAMS	121f08	COL1D3, Seat Track near A3	0	-90	0	378.11	246.46	234.96
	SAMS	es08	COL1F2, MSG, Ceiling Plage Y1-B1 Y2-A1	0	90	90	475.63	204.91	159.95

System Characteristics

	SAMS	MAMS
Frequency Range (Hz)	0.01 to 400	< 0.01
Resolution	< 1 ug	~ 3 ng
Dynamic Range (dB)	~ 132